Many critics say biofuels have not lived up to their environmental promise so far, but that could soon change.

Is it time to bring in plan B for biofuel?

By Fred Pearce, *NewScientist*

Ten years ago, running your car on biofuels meant covertly topping up your tank with chip fat. Now petrol is routinely mixed with ethanol made from corn, and diesel with squeezed rape (canola), oil palm and soybean oil.

The current generation of biofuels was rushed onto the market in response to escalating concern in Europe about climate change, and in the US about energy security. But almost before the biofuels industry has got going, it has run into major problems. It has swiftly become a victim of its own success, gobbling up land and water in a way that has frightened the world.

The charge sheet – it seems – grows by the month. Biofuels are crowding out conventional crops and raising food prices. The corn required to fill an 4WD tank with bioethanol just once could feed someone in Africa for a year.

What's more, the environmental benefits are uncertain. In theory the growing crops soak up as much carbon dioxide as is made burning them. But in practice, the cultivation and processing of corn in particular takes a large amount of energy, resulting in additional greenhouse gas emissions that can cancel out this benefit. Cultivating soybean or oil palm can also add to global warming if the crops are grown on former rainforest land or drained peat bogs.

Second generation biofuels

Thankfully though, we now have a plan B, in the form of second-generation biofuels made from inedible plant material that can be grown on unused land or, even better, from plant or organic waste such as corn straw, wood chips or the contents of landfill.

The theory is that such material will not require cultivation and therefore will have low carbon emissions. Work has begun on several pilot plants aimed at bringing these fuels to a forecourt near you.

The big money at the moment is going into cellulosic ethanol – ethanol made from the bits of plants we cannot eat. Edible starch – the stuff currently turned into bioethanol – makes up only a small proportion of the total biomass of plants. Most biomass is a woody, indigestible mixture of lignin and cellulose, bound up in plant cell walls.

Lignin will burn, but has so far defied efforts to convert it into liquid fuel.

> ***"The big money is going into ethanol made from the bits of plants we cannot eat"***

But cellulose, like starch, is made up of long chains of glucose that can be fermented to make ethanol.

The bad news is that separating cellulose from lignin and breaking it down into its component sugars is still far more difficult and expensive than doing the same to starch. The cost of producing cellulosic ethanol from corn, for instance, is currently 50 per cent higher than for making bioethanol from starch.

Cutting the cost

Finding ways to cut those costs is the number one priority for biofuels technologists, and hundreds of millions of dollars are being devoted to the task. In the US alone there are 30 projects in the pipeline to develop cellulosic ethanol 'biorefineries', with half a dozen of these dipping into a government development fund worth $385 million.

Essentially the job is to hydrolyse the cellulose, or break it down into its sugars using water. The task requires either a chemical catalyst like acid or a biological catalyst, usually an enzyme. The biomass is first treated to dissolve the lignin, and after hydrolysis, the resulting sugars are fermented with brewer's yeast to create ethanol.

In May 2008, the first biorefinery designed to demonstrate the technology opened in Jennings, Louisiana. It will process bagasse – what's left of sugarcane after the sugar has been squeezed out of it. The company behind the project, Verenium of Cambridge, Massachusetts, says it is processing the bagasse using its own proprietary enzymes and will build a commercial plant next year.

It may not be the first, though.

Genencor, in Rochester, New York, makes industrial enzymes and, in April, the company announced plans with chemicals giant DuPont to build a similar plant using corn husks and bagasse as feedstock.

Companies aiming to convert cellulose into ethanol using the chemical process are not far behind. This technology dates back to the 1920s, when German chemists developed the Fischer-Tropsch process, which turns coal into gas and then a liquid fuel by pyrolysis – heating in the absence of oxygen.

Turning cellulose into biofuels

Now the process could get a new lease of life turning cellulose into biofuels. In

CAN BIOFUELS COOL THE PLANET?

Biofuels may have a tarnished image today, but they are still the only renewable energy technology that actually sucks carbon dioxide out of the atmosphere. Producing them could one day help lower CO_2 levels in the atmosphere.

Consider this. Our climate problems arise because we dig up long-buried carbon and burn it, thus pumping carbon dioxide into the air. Biofuels could put the system into reverse. Currently, the CO_2 absorbed from the atmosphere as biofuels grow is returned to the air when they are burned. But what if the gas could be captured?

The technology for capturing CO_2 emissions and burying them out of harm's way is being developed for fossil fuels. If the CO_2 from burning biofuels could be similarly captured, we would have a mechanism for lowering atmospheric CO_2 levels.

This has not yet been widely discussed because biofuels are mainly produced for transport fuel and nobody has come up with a technology for capturing and burying exhaust emissions. But many experts predict that the electric car will be the next big breakthrough in transportation.

If generators burned bioethanol to produce the electricity to run our cars, then buried their emissions, they would effectively be sucking carbon from the air. Driving would be helping cool the planet rather than cook it. Who knows? Big cars could be compulsory – driving them a civic duty.

April, Colorado-based Range Fuels announced plans to build a plant to pyrolyse logging waste and then pass the resulting "syngas" over a proprietary catalyst to convert it into ethanol.

But the costs remain high for both methods. The chemical process is energy intensive, while the enzymes used in the biological approach are costly and inefficient, slowly converting less than half of the available biomass to alcohol.

In a bid to reduce the cost of the biological process, Mascoma of Boston has hooked up with General Motors to build a pilot plant in Rome, New York, that will deploy microorganisms to both convert switchgrass cellulose into sugar and ferment it, in a single and therefore cheaper step. The technology is based on research into the use of cellulose-converting organisms, such as the bacterium *Clostridium thermocellum*, by Lee Lynd and Charles Wyman at the Thayer School of Engineering at Dartmouth College in Hanover, New Hampshire. The plant is set to begin producing bioethanol later this year.

Enter, genetic engineering

Meanwhile other companies are investigating the use of genetically engineered microbes to improve the efficiency of the process and bring down its cost.

The Canadian biotech firm Iogen, a specialist enzyme manufacturer and longtime pioneer of cellulosic ethanol technologies, has been genetically engineering tropical fungus to make enzymes that will eat straw. Other researchers believe bacteria in the guts of termites, which have had millions of years of practice at eating wood, could fit the bill.

And Craig Venter, the genomesequencing pioneer, has been collecting marine microorganisms with the aim of building new bacteria from scratch to produce the perfect enzyme.

Modifying the crops

In parallel with these developing technologies, researchers are also engineering the crops themselves for better yield, easier processing and lower environmental impact. Some are busy trying to make plants with less lignin, others are working to create cellulose that can be broken down more easily.

This research raises concerns for environmentalists. Many believe that all the talk of cutting the environmental impact of biofuels by processing waste biomass will wither away as crops designed for cellulosic ethanol manufacture come on stream, leaving us back where we started.

Technologists counter that much less energy should be burned up in making second-generation fuels. Also, some biofuel plants will burn the lignin left behind when the cellulose has been liberated, providing energy for the production process. The feedstock is also either farm waste or weeds, neither of which require the use of harmful pesticides or fertilisers.

So which approach will win out? There may be no single winner, says Ross MacLachlan of Canadian company Lignol Energy, which wants to use Canada's forests to make ethanol. "There will be a lot of technologies out there. Any of them will be appropriate for different feedstocks and in different parts of the world."

Big research dollars are examining cellulosic ethanol – ethanol made from the bits of plants we can't eat (such as corn stover pictured) – and how to reduce production costs. (Photo: Wally Wilhelm)

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