

## Biofuels: can they help power our future?

Have we seen the end of cheap oil? There is enough oil to keep us going for a long time yet, but the cost of finding, extracting and refining it into a useable product is likely to get more expensive. There is also the problem that oil and other fossil fuels such as coal contribute large amounts of greenhouse gases to the atmosphere.

So researchers worldwide are scrambling to find alternatives. Biofuels, or fuels made from anything that is or was recently a plant, and other organic sources such as bacteria, are being pursued as viable options.

There many ways to create biofuels, however, a number of technical, economic and social challenges exist that, at the moment, are preventing them rapidly replacing fossil fuels and our transition to a biofuel economy.

This fact sheet will present an overview of the key biofuels, their potential, and technical and social issues facing them.

### Getting biofuel

Any plant is a renewable resource that can trap carbon and help reduce greenhouse gases in the atmosphere. When a plant is used as a feedstock for biofuel the carbon is released back into the atmosphere, in effect making the biofuel carbon neutral, unlike fossil fuels. But energy is required to grow the plant and extract the fuel and therein lies the task for scientists: finding plants or organic sources (feedstocks) that are plentiful, inexpensive to grow or source, do not compete with food production and involve a fuel extraction technology that is simple and energy efficient, preferably one that produces a lot less greenhouse gas than would be produced if a fossil fuel was used.

### Biofuel feedstock

Generally, biofuels are a solid or liquid. Solids (biomass) are generally waste plant material that is burnt and used to generate electricity in the same way coal is. The two most common forms of liquid are ethanol and biodiesel.

At the moment the following feedstocks are being used as a source of biofuel, or are the subject of research investigating their potential:

- Corn (maize)
- Sugarcane
- Oilseeds (eg, mustard, palm oil, canola, soybean)
- Algae
- Woody weeds and grasses
- Animal fat (tallow) and used cooking oils
- Crop trash from agriculture and forestry
- Municipal and industrial waste streams (eg paper manufacturing)

## First versus second generation

First generation biofuels are those produced from technology in use today. These include ethanol from sugar cane and corn, and biodiesel from oil seeds, old cooking oil and tallow. They also include biomass such as crop and forest trash that is burnt for energy. Second generation fuels are those extracted using technology still being developed. Feedstocks for second generation fuels include algae and cellulose-based plant material that includes biomass. Technically, there is a potential third generation: biofuel from genetically engineered or synthetic bacteria and plants that produce hydrocarbons or fuels directly.

Second (and third) generation biofuels are considered more viable because of the predicted lower energy requirements to extract the fuel and the likelihood they will compete less with land used for food production.<sup>1</sup>

## Kitchen chemistry

### Making biodiesel

Making biodiesel is actually kitchen chemistry, though your kitchen variety is likely to damage your engine (and your kitchen). Biodiesel is formed through a chemical process called “transesterification”. This occurs when you mix your oil with an alcohol, such as methanol or ethanol, and an alkaline reactant such as caustic soda (sodium hydroxide) or potassium hydroxide. The alkaline reactant acts as a catalyst – a molecule that speeds up a chemical reaction.

The resulting chemical reaction will form two layers: a bottom layer of glycerine (a useful byproduct) and a top layer of biodiesel.

Your oil can be from oil seed crops, used cooking oil, or animal fat, algae and even woody plants.

### Biodiesel potential

There are many factors that influence the viability of a feedstock, including the energy required to grow, fertilise, harvest and process the crop. A 2007 CSIRO report<sup>2</sup> found that using pure biodiesel or blending biodiesel with standard fuel can reduce greenhouse gas emissions, but this is dependent on the feedstock. Used cooking oil resulted in an 87 percent reduction in greenhouse gas emissions compared to getting the equivalent energy from fossil fuel diesel. Palm oil grown in plantations established prior to 1999 also scored well, but palm oil grown in recently established plantations that required the clearing of rain- or peat forest actually produce more greenhouse gases than diesel from fossil fuels. This is because land

clearing of such forests releases large amount of carbon dioxide and methane, more than can ever be made up for by turning the land into palm oil plantations and creating biofuel.

The CSIRO and other reports<sup>3</sup> also show that particles from the exhaust pipe of cars and other noxious emissions such as carbon monoxide are generally lower with biodiesel compared to fossil diesel. Biodiesel is also potentially better at lubricating engines compared to low-sulfur fossil diesels, reducing engine wear<sup>3</sup>.

### **Biodiesel problems**

Nitrous oxides (greenhouse gases) from the exhaust pipe can be higher, depending on factors such as engine make and biodiesel type.<sup>2, 3</sup>

Feedstock such as palm oil grown in recently established plantations that required the clearing of rain- or peat forest can increase greenhouse gas emission 36 to 150 times higher than if the diesel was produced from fossil fuels.<sup>2</sup> Crops such as canola are often grown on productive agricultural land that would normally grow food. This has caused some to speculate that this could lead to increases in food prices and exacerbate any potential food shortages in the future.<sup>4</sup>

### **Making ethanol**

Ethanol, or ethyl alcohol, is often used as a blend in petrol and is the same alcohol that is in your beer, wine or vodka. Common feedstocks include corn, potato and sugar cane. Generating ethanol from these feedstocks is a simple process of fermentation followed by distillation and dehydration. Fermentation is the use of microbes or yeast to convert the sugars and starches from the plant into ethanol. Cellulose is also constructed of simple sugars and starch and can be converted to ethanol, but the technology to do this is not yet economically viable. Distillation is important to remove the water from the ethanol, but it only removes about 95 percent of it. Dehydration removes the rest.

### **Ethanol potential**

Ethanol is an old fuel, though a relatively new industry in Australia. Many petrol stations in Australia now supply petrol blended with up to 10 percent ethanol. The first generation technologies are well proven though they have their limitations. The primary feedstocks in Australia are the by-products of sugar cane and wheat processing. In the United States, by comparison, corn (maize) is a primary feedstock. CSIRO estimate that even with today's technology ethanol could replace 5-10 percent of Australia's petrol consumption. Europe and Brazil already have cars that run on 85 percent ethanol blends.

### **Ethanol problems**

Corn is one of the main feedstocks for ethanol production but extracting it directly from the starches and sugars in corn (1st generation fuel) is thermodynamically inefficient. That is, the energy value of the ethanol is often less than the energy required to produce it.

Corn and many of the other crops used as feedstock at the moment use lots of water, fertiliser and land that could be used for food production.

Sugarcane as a feedstock is a possible exception in the first generation biofuel technologies. Growing sugarcane generally requires less fertilizer and water helping make the energy required to produce the ethanol less than the energy value of the ethanol itself, though it is still grown on land used for food production. They can and do also use the left over cane trash (bagasse) to burn and produce electricity.

# Second generation case-by-case

## Cellulose

Cellulose is tough stuff. It is simple sugar molecules glued together and is what gives a plant its structure. It is especially prevalent in the woody plants and is a potential source of biofuel – ethanol, diesel and other fuels.

### Cellulose sources

The key sources for cellulosic fuels are those plants that can be grown on marginal or non-arable land (woody plants and grasses) or biomass, which is waste products from agriculture (crop trash, manure), forestry (thinnings, sawdust) and industry (construction debris).

### Cellulose status

Locked up in cellulose is energy in the form of sugars. To get that energy you need to first break down the fibers (glue) in cellulose that bind those sugars together. And this is the technical hurdle preventing this becoming a viable technology at the moment. The technology to do this has been around for decades, but either the reactors required to do this are prohibitively expensive, slow and energy intensive, or the fuel is poor quality and unsuitable for engines. So, scientists are experimenting with various methods of unlocking the cellulose-bound energy in a simple and energy-efficient way. This can include heat, extreme acids or bases, even genetically modifying bacteria that produce cellulose-busting enzymes. Other research is focusing on the feedstock themselves by using modern biotechnology to select for strains of appropriate species that make them suitable for biofuel production.

### Cellulose research

CSIRO has set up a Crop Biofactories Initiative.<sup>5</sup> Part of this initiative is investigating insect genes involved in lipid metabolism and production of enzymes that degrade cellulose. The aim is to increase the efficiency of converting the cellulosic plant materials such as wood, leaves, straw into biofuels.

There are large numbers of microbial and other useful organisms having their genomes sequenced to find genes that could have a role in breaking down cellulose or degrading biomass. High priority genes are those that code for enzymes that can function in acidic environments or high temperatures.<sup>6</sup>

Some of these microbes have been found in the gut of termites. Research on the termite has revealed hundreds of genes coding for wood-munching enzymes exuded by the microbes.<sup>7</sup>

### Cellulose potential

Feedstock is cheap and many can be grown without competing with land for food production, especially if the plants are native to the area — native plants require less care and therefore fewer energy inputs to reach a harvestable size.

Predictions are that fuel from biomass can be produced without the high carbon footprint of the first generation biofuels.<sup>6</sup>

### Cellulose problems

High cost of processing the cellulose is inhibiting the emergence of the industry at the moment.<sup>8</sup>

For some feedstocks arable land may be needed that could otherwise be used for food production,

for example, grasses such as switchgrass being researched in the United States is, likely to compete in some areas for food or grazing.

There is the potential issue of supplying the biomass feedstock at high enough levels to have a meaningful effect on supply and sustainability challenges.<sup>8</sup>

### **Algae and other microbes**

The cell membranes of algae are full of fat making them a convenient source of oil for biodiesel and other hydrocarbon-based fuels. The dry weight of algae can contain 10-30 percent oil, even higher for some species.<sup>9</sup>

Algae can be grown in waste or non-potable water or seawater. They can even be linked up to coal-fired or other fossil fuel-generated power plants where waste carbon dioxide is piped to the algae to drive photosynthesis.

### **Algae status**

Algae are diverse, highly productive and don't necessarily require productive farm land to be grown for biofuel. A CSIRO report<sup>9</sup>, however, states that although algae are widely grown in aquaculture to produce various high-value foods, nutraceuticals and chemicals, the methods adopted are yet to be economically and ecologically viable for the production of biodiesel in quantities large enough to replace fossil fuels. There is a lot of research happening worldwide, however, to suggest this situation may change within the next 10-15 years.

### **Algae research**

In Queensland, James Cook University has opened an algal biofuel research facility to develop algal carbon capture and storage. In trials, the 5000-square metre research plant produced 14,000 litres of oil and 25,000 kilograms of algal feed for livestock for every 100 tonnes of carbon consumed. Phase two is to construct test facilities at coal fired power stations in Queensland, NSW and Victoria.

Australia's Murdoch University and the University of Adelaide have begun a project to turn vast salty ponds of algae into biofuels.

Canadian and Indian scientists have figured out a way to milk algae for their oil. They have genetically modified diatoms (single cell algae with intricate shells) so that they actively secrete oil products. This means you don't have to destroy the algae and re-grow them to extract the oil.<sup>10</sup>

### **Algae potential**

CSIRO research<sup>9</sup> has shown that it is possible to produce algal biodiesel at a lower cost and with less greenhouse gas emissions than fossil diesel, but only under ideal conditions. CSIRO's analysis of the potential of two algal biodiesel pilot plants, one in South Australia, the other in Western Australia, found that when compared to the use of food crops for the production of biodiesel, the design of the algal farms have a comparatively low environmental impact. The viability of the algal ponds, however, relied on the assumption that the ponds were sited close to an industry that produced CO<sub>2</sub> as a waste gas. The CSIRO study assumed an ammonia and power plant in their calculations. CO<sub>2</sub> from these plants could be captured and fed into the algal ponds to enhance photosynthesis. The algae could also be made to produce methane, which can be pumped back to the power plants to generate electricity, offsetting fossil fuel combustion. The

report's authors conclude that economic viability is highly dependent upon algae with high oil yields capable of high production year-round, which has yet to be demonstrated on a commercial scale.

But the research is in its infancy and there is plenty of optimism about the potential of algae. Synthetic Genomics and ExxonMobil Research and Engineering Company (EMRE) have gone into partnership to research and develop more efficient and cost effective ways to produce algal biofuels. Synthetic Genomics speculate that algae could yield more than 3600 litres of fuel per hectare of production per year. This is up to three times more than any of their land-based rivals such as palm oil and sugarcane.<sup>11</sup>

### **Algae problems**

If the algal farm is to tap into and capture all the CO<sub>2</sub> from a power plant their needs to be sufficient land nearby to build algal farm large enough to do this. CSIRO identified that in Australia many industries lack this capacity.<sup>9</sup>

Except in ideal situations as described above, the cost of algal biodiesel today would still be more expensive than diesel derived from fossil fuels, though the economics may change as technology improves and if the cost of fossil fuel rises.<sup>9</sup>

## **Other technologies**

### **Synthetic biology**

If successful, synthetic biology will be an example of third generation biofuels. Synthetic biology goes further than genetic modification; it potentially rewrites or constructs whole genetic codes to build a designer organism from the ground up. Bacteria and microbes are key components of this research and scientists working in this field hope to create microorganisms with the genetics to produce various hydrocarbon-based fuels directly and do away with any of the processing and refining steps.

### **Synthetic biology problems**

Key concerns are safety and security, based on the perceived risk of harmful organisms being released, either deliberately or accidentally, into the environment.

For some groups of people, synthetic biology could raise ethical questions pertaining to the creation of synthetic biology: scope, applications and implications.

### **Of interest**

<http://syntheticbiology.org/>

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### **More information**

Further discussion on nano- and other emerging technologies can be found at the TechNyou web site and blog: [www.technyou.edu.au](http://www.technyou.edu.au)

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