Biofuels in a Clean, Green Future

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Ian Lowe examines the birth of the biofuels imperative and how biofuels fit into a sustainable future.

Biofuels are derived from living things. Historically, early human development relied almost entirely on wood, but the move to fossil fuels began when England became short of wood in the late 18th century. The shortage was primarily driven by massive use of wood to expand the navy, compounded by the effects of a growing population.

At the time, coal was considered an inferior fuel to wood. It was dirtier, more difficult to obtain and thus more expensive.

Firewood is still a significant heating source in many parts of the world. In Australia it still dominates domestic heating in Tasmania and is important in rural areas of the other eastern states.

Our industrial civilisation has been largely powered by fossil fuels:

- coal is now mainly used for electricity;
- oil and its derivatives are mainly used for transport fuels; and
- natural gas.

Recent growing interest in biofuels has been driven by two forces. It is now accepted that our burning of fossil fuels is changing the global climate and risking dangerous shifts in the whole climate system. Less widely appreciated is that we are approaching or beyond the peak of world oil production, so there is an urgent need to find replacement fuels for our transport system.

Global Climate Change

Carbon dioxide levels in the atmosphere have varied between about 180 and 280 parts per million for the past half-million years. The figure is now above 380 parts per million and increasing rapidly. This is a direct result of the burning of huge amounts of coal, oil and gas since the Industrial Revolution.

The Earth is now about 0.7°C warmer than it was 100 years ago, with consequent changes to rainfall patterns, plant growth, the distribution of animal species, sea levels and the frequency of severe events like storms, floods and droughts. All the projections suggest the situation will get much worse.

The United Nations' advisory body, the Intergovernmental Panel on Climate Change, gave in its fourth assessment report a range of possible future outcomes depending on the pattern of future fuel use and taking into account uncertainties in the science. The most optimistic future, based on a rapid phasing out of fossil fuels and the best interpretation of the scientific uncertainty, still involves a further 1.5°C increase in the average global temperature, with associated changes in other outcomes influenced by temperature.

This is why the governments of the industrial nations have agreed to begin a process to reduce emissions of carbon dioxide. The first step was the Kyoto Protocol, agreed more than 10 years ago. At the 2007 Bali conference, an agreement was reached to negotiate the next phase of reductions to apply beyond 2012. Every day more scientific evidence shows the urgency of a concerted global response.

Peak Oil

Petroleum reserves are not unlimited. About 70 years ago, M. King Hubbert used statistical data on US oil discoveries and associated production to predict that US oil output would peak in about 1970. It did, leading to a change in the relationship between petroleum-producing nations (OPEC) and those that use oil. The 1970s oil "shocks" dispelled the myth of infinite resources, causing significant policy changes in many Northern Hemisphere countries.

Hubbert's technique was used in the 1970s to estimate that world oil production would peak about 2010. That is close to the current best estimate: there are optimists who think the peak might be as far away as 2015, while there are pessimists who think it happened in the year 2003! Whoever is right, there can be no escaping the fundamental geological truth that we are using petroleum much faster than it was produced naturally, so it will not be plentiful for much longer.

The most likely future for biofuels will involve small-scale production for local use, taking advantage of by-products like crop residues and other waste materials.

Some analysts think the struggle for the remaining oil is already under way. Professor Gretchen Daily of Stanford University posed a rhetorical question to a forum in Sydney in 2003: "How concerned would the US administration be about human rights in Iraq if it had 10% of the world's broccoli?"

Most decision-makers are still in denial about the approach of the peak in world oil production. Our transport planners assume that fuel will always be plentiful and cheap.

Although fuel prices in Australia are much higher than in North America, they are much lower than in Europe. Despite recent increases, we still pay more per litre for beer, cask wine, milk, orange juice or even bottled water than we do for petrol or diesel! Fuel is much cheaper in Australia than in Western Europe, where people use much less. It is even cheaper in North America, where people use more.

Many urban commuters in Australia and North America now drive long distances as sole occupants of large and inefficient cars. The situation is being worsened by increasing use of four-wheel-drive vehicles to cope with the "rugged terrain" of suburban streets. A recent survey in Australia found that drivers no longer feel safe on the road in sedans, given how many large four-wheel-drive vehicles are on the road! So they are buying urban assault vehicles in response. This is an urban arms race, leading logically to armoured cars, tanks and Humvees on the street!

Even if petroleum reserves were unlimited, climate change would require us to look seriously at ways of reducing its use. Future generations will find it difficult to believe that we drove alone in commuter vehicles; they will be startled to learn that we fuelled vehicles and raced them around a track just to see which was the fastest.

Alternatives

We don't have to burn coal to generate electricity. For several decades, the residue from crushing sugar cane, known as bagasse, has been used in Queensland to generate the electricity used to crush the cane. It provides a surplus that can be distributed locally. With increasing concern about climate change, there is growing interest in using other crop residues like the thinnings and residues from forestry operations, or the straw left behind when grains like wheat are harvested. Using these biological residues would obtain energy from the carbon they have taken from the atmosphere during their growth, so it would reduce the release of fossil carbon.

In the short term, some use can be made of other fossil fuels for transport. Most Australian taxis now run on liquefied petroleum gas (LPG), and increasing numbers of buses use compressed natural gas (CNG). But these are also using limited resources, and they put fossil carbon into the air.

It is possible to produce liquid fuels from coal; the entire German war effort during World War II was powered by these synthetic fuels as Germany had no oil. The technology was updated and improved by South Africa in the 1970s. The problem is that this process produces much more carbon dioxide per unit of fuel than burning petrol. The concern about climate change has effectively ruled out a group of alternative liquid fuels derived from coal, oil shale and tar sands.

A second group of fuel alternatives can be produced sustainably from plant material. Australia has produced ethanol from sugar since the 1930s, while Brazil and the US also produce large quantities from sugar and maize, respectively. Ethanol can be used as a fuel extender by blending it with petrol for use in standard petrol engines, or engines can be modified to run on pure ethanol. E10 blends were widely used in Australia in the 1940s and are now available again at most retail outlets.

Ethanol, or ethyl alcohol, is produced by fermentation of sugars. This is the process used to produce wine from grapes and beer from grain. Spirits like whisky, brandy and vodka are produced by distilling fermented liquids to increase the alcohol concentration.

Other liquid fuels can be produced from plant material. Methanol, or methyl alcohol, can be obtained by pyrolysis or "destructive distillation" of plant material. Again, methanol can be blended into petrol as a fuel extender or used to run modified engines.

Finally, a wide range of vegetable oils can be used to run diesel engines: used oil from fish shops, peanut oil, sunflower oil, olive oil and so on. Many farmers have begun producing their own diesel fuel from oily plants.

All these biofuels have in common two advantages. They can in principle be produced sustainably, so their use is not depleting resources. Secondly, they extract carbon from the atmosphere when growing, and release it in burning, so they don't add to the growing problem of climate change.

Shortcomings

There are three problems with ethanol. Significant amounts of transport fuel are required to collect and process crops like sugar, so the energy benefits are small or possibly even negative; in other words, the fuel energy used to produce the ethanol is about the same or maybe less than the fuel value of the product. The second problem is that growing sugar leads to other environmental problems. In Australia, its production pollutes the waters around the Great Barrier Reef, while clearing lowland rainforest for farming destroys habitat and thus threatens biodiversity. The third problem is the ethical dilemma of whether it is appropriate to use food-growing land to produce transport fuel in a world where millions go hungry.

The scale of the potential contribution is also limited: converting Australia's total sugar production to ethanol would meet about 10% of our transport fuel needs. In the case of methanol, a 1979 CSIRO study found that pyrolysis of rapidly growing trees could produce all of Australia's transport fuel, but it would require an area about the same as what is now devoted to all agricultural purposes!

Thus plant-based alcohols may be a useful supplement to petroleum fuels, but they are unlikely to be produced on a scale sufficient to be a replacement. Even if they could, there would be questions asked about whether this should be a priority use for productive land.

There is international criticism of the US policy of subsidising maize production for ethanol, because this now converts into transport fuel an amount of grain roughly equivalent to Thailand's rice crop. In a world of food shortages there will be more pressure to make the best use of land.

There is also increasing recognition of environmental problems arising from biofuel production. Clearing Malaysian rainforest to produce palm oil has not only destroyed habitat and put pressure on endangered species, but has also exposed peaty soils to the tropical sun, causing fires that put extra carbon into the atmosphere.

The Future

The most likely future for biofuels will involve small-scale production for local use, taking advantage of by-products like crop residues and other waste materials. I am sure we will see increasing on-farm use of locally produced biodiesel as well as more electricity generated from biological wastes. Biofuels will be an important component of the shift away from fossil fuels, but only a minor contributor unless

What Is Driving the Growth of Biofuels?

COMBATING CLIMATE CHANGE

Transport is a significant contributor to climate change, accounting for around 25% of man-made greenhouse gas emissions globally.

In principle, the use of biofuels can help reduce transport's impact on climate change. This is because the plants used to make biofuels absorb carbon dioxide (CO_2) – the most important greenhouse gas – as they grow. The gas is later released when the biofuels are used.

However, biofuels are not carbon-neutral. It takes energy to grow and harvest the plants and to process and distribute biofuels. The entire process emits CO_2 and fertilisers emit nitrous oxide (N_2O), a powerful greenhouse gas.

The amount of energy needed to make different biofuels varies considerably. This makes it vital to take the entire production process into account when assessing the potential of biofuels to help reduce transport CO_2 emissions.

TECHNOLOGY AND INNOVATION

Unlike other renewable fuels, such as hydrogen, the infrastructure to manufacture and distribute biofuels is in place today. Biofuels are also compatible with today's vehicles and power generation technology.

In 2006, $26 billion was invested in biofuels, according to the United Nations Environment Programme (2007). The International Energy Agency (IEA) estimated in its *World Energy Outlook 2006* report that between 2005 and 2030 it will cost $160 billion to expand biofuel production to fuel 4% of global road transport, and $225 billion to fuel 7%.

ENERGY SECURITY

Global energy demands are increasing rapidly. The world's population has doubled in the past four decades to around 6.6 billion in 2004, and according to the United Nations is expected to exceed nine billion by 2050. Rapid development, particularly in China and India, is increasing wealth and this is boosting demands for energy and transport. There were around 900 million vehicles on the road in 2000, but this has been forecast by the World Business Council for Sustainable Development to increase to over two billion by 2050.

Fossil fuels (oil, coal and gas) are expected to be the dominant source of energy for the foreseeable future. But production has already peaked in many major oil-producing countries and new developments are increasingly located in environmentally challenging and politically unstable parts of the world. This has resulted in high oil prices, which the IEA predicts will remain at US$48–$62 per barrel until 2030. High oil prices hit developing countries the hardest – some spend six times as much on fuel as on health, according to a 2007 United Nations report (*Sustainable Bioenergy: A Framework for Decision Makers*).

Biofuels are seen by governments as a secure source of energy and a way to reduce their reliance on imported fossil fuels. Brazil has replaced around 15% of its petrol consumption with bioethanol, according to the 2006 IEA report. In August 2007, the *Washington Post* put this figure at 40%.

RURAL DEVELOPMENT

Biofuels can help boost farm incomes. Globalisation and the industrialisation of farming have reduced the price that farmers get for their produce. Demand for the agricultural commodities used to make biofuels is reversing this trend. In the developed world this is creating jobs and reducing the need for subsidies for farmers.

Adapted with permission from *Promoting Sustainable Biofuels* (http://www.unilever.com.au/ourvalues/environmentandsociety/issues/Renewable-energy-and-biofuel). Courtesy: Unilever

there are significant new developments. One research project looks particularly interesting as it is turning a problem into an opportunity. The waters of the Coral Sea are rich in nutrients because of farming practices in northern Queensland. A group at James Cook University has shown that this water can be used to grow algae, which in turn can be processed to give biodiesel. This process will potentially both replace fossil fuel and clean up the water around the Great Barrier Reef.

In considering transport alternatives we should look at the whole system. Some people argue that the problem is not oil and car engines but the overall inefficiency of the vehicle fleet. They have a point. Imagine a group of engineering students being asked to design a transport vehicle to carry a fragile payload weighing 50–100 kg. If they produced a design for a vehicle that weighed more than 1 tonne, their tutor would probably suggest they revise their career options and steer them toward a future that would not demand numeracy. The Amory Lovins hyper-car weighs about 250 kg and uses one-fifth the fuel of the average modern car. Cars like that would make the oil last much longer and dramatically reduce emissions.

Other people go back one step further and see mobility as a response to poor urban design. Again, they have a point. We move into cities to access the social, economic and cultural services available there, not to spend hours travelling to those services. So we need to improve urban design to make essential services accessible, rather than building concrete jungles of roads, tunnels and overpasses to let people drive to inaccessible services.

These are relevant criticisms. We should, of course, encourage improved urban design and smaller, more efficient vehicles. But these measures have long time scales. Much of the structure of the cities of 2030 is already in place. Most of the vehicle fleet of 2015 is already on the roads. We need to be pursuing cleaner energy systems as well as demanding better vehicles and more intelligent urban planning. Like the other problems I have discussed, these issues should not deter us from developing biofuels, but they provide the wider context for that work.

Working toward sustainable futures is a moral imperative. It is indefensible to be developing futures that we know cannot be sustained, producing inevitable problems for future generations. A sustainable future will have a stabilised population living within the limits of natural systems, using cleaner fuels and using them more efficiently. Biofuels will be an essential component of that clean, green future.

Flinders Research Boosts Biofuels Potential

A biofuel additive developed by Flinders University could significantly boost biofuel use in Australia following the product's commercialisation by the university's industry partners.

The additive lowers the temperature at which tallow-based biodiesel solidifies, a problem that causes fuel flow difficulties and has constrained the take-up of biofuels made from the waste products of abattoirs.

Leader of Flinders Materials and Bioenergy Group, Dr Stephen Clarke, said there "is a huge potential market for tallow-based biofuels, with the current consumption of petroleum diesel being around 15 billion litres annually in Australia".

"The additive that Flinders has developed removes one of the major impediments to the use of tallow-based biofuels, and this market could expand considerably, perhaps to around one billion litres a year, when our product can be added to biofuel blends," Dr Clarke said.

Meat and Livestock Australia has secured a provisional patent over the University's additive, which can lower the solidification temperature of tallow-based biodiesel or diesel blends by about 5ºC to around -6ºC. The temperature difference will boost the potential to use tallow-based biofuel in colder parts of Australia and cooler climates in Europe and elsewhere.

Meat and Livestock Australia is now commercialising the additive with other industry partners. Dr Clarke's research team will play a key role in that process as they scale up the production of the additive from laboratory to commercial quantities.

Biodiesel fuel is generally prepared from a blend of lipids, such as used cooking oils, tallow and vegetable oils such as canola, soybean and palm oil. The use of Flinders' additive could significantly increase the proportion of tallow-based fuel that could be included in such blends.

Flinders is also exploring the potential of developing fuels from microalgae and cellulose and wood waste.

Source: Flinders University