Are biofuels the future or a folly?: A review

This is a summary and review paper following the Biofuels Forum with this title organised by the Canterbury Section of NZIAHS and held at Lincoln University on 27 August 2008.[1]

Biofuels - what are they?

We use 'fuel' to mean a transportable source of energy, particularly those which are liquid, but not excluding solids such as wood and coal or gases such as hydrogen or compressed natural gas. 'Biofuels' are derived from biological material. So crude oil (petroleum) is a fossil biofuel, most of it having been produced aeons ago by marine organisms subjected to intense heat and pressure in suitable geological environments. In post-peak-oil days the pressure is on to produce renewable biofuels, especially to contribute to maintaining means of mobility. Nearly all of Earth's energy resources derive from solar energy by one route or another; tidal currents and radioactive materials are arguably exceptions. But nothing has yet been found for transport purposes to quite match the convenience, compact density and high energy content of fossil-oil-derived liquid fuels.

Electrical energy is a wonderful vehicle mover, with many advantages. Once on-board generation (fuel cells) or compact, high-power, high-storage batteries are improved, electric vehicles will suit New Zealand's hydro-rich, wind-rich, wave and tide-rich environment. But at least until then, we will need biofuel supplementation of dwindling and escalating-cost fossil oil fuels. Photosynthesis in our low-population-density, land-rich country, like high water (for hydro), strong winds and strong tidal currents, is a gift we should not ignore.

Several decades ago, after the 1970s 'oil shocks', my then colleague, George Davies, spoke of the four useful 'F's derived from 'Fotosynthesis': Food; Fibre; Fuel and 'Farmaceuticals'. Biofuels in New Zealand should be produced in harmony with the other three 'F's, not in harmful competition with them. The difference between on-farm production cost and farm-gate value is a major driver of what farmers grow, but it acts alongside incentives, regulations and grower preferences.

Caught between generations

In New Zealand, we are caught between the old and the new biofuels. So-called 'first generation' biofuels often have low values of energy ratio (e.g. useful vehicle energy out: total production and distribution energy in) and unwanted side effects, like displacing food crops from limited arable land[1]. 'Second generation' biofuels[2] hold out promise of overcoming such disadvantages, but very few are yet market-ready.

Leaving aside the special cases of fossil biofuels: petroleum and petrified compressed wood (i.e. coal), some of the old biofuels are very old indeed. Well before internal combustion and compression ignition engines appeared on the scene in the late 19th century, both animal and vegetal oils were used for lighting: whale oil and tallow; castor, linseed and peanut oils. Alcohols have been used since ancient times for beverages, at least as far back as the Babylonians and Sumerians[3] and possibly earlier. Yeast fermentation is one of the oldest chemical technologies serving humankind.

In 1895 Rudolf Diesel (1858-1913) ran his first engine on peanut oil; he showed it at the World Exhibition in Paris in 1900 and said in 1912: "The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in the course of time as important as the petroleum and coal tar products of the present time." In 1908, Henry Ford (1863-1947) designed his Model T Ford to run on a gasoline/ethanol (i.e. petrol/alcohol) blend, calling it "the fuel of the future" to a New York Times reporter in 1925[4]: "The fuel of the future is going to come from fruit like that sumach out by the road, or from apples, weeds, sawdust almost anything." he said. "There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years." Modern life cycle analysis might reduce Henry's numerical estimate somewhat, but the principle remains valid.

Fermentation of sugar from crops like sugar cane continues to supply bioethanol, notably and successfully up to about half the transport fuel needs in Brazil. Use of cellulosic material from crops like maize ('corn' in the USA) is fraught with more pitfalls and debate; energy ratios are sufficiently close to unity (as much out as is put in, with most of the latter from fossil oil) to provide more fuel for argument than for transport and competition for arable land has contributed to global increases in prices of grain for food[5]. Ligno-cellulosic sources are something of a 'holy grail' for bioethanol advocates; successful pre-processing and co-products could mean that purpose-grown crops, like switchgrass or specific willow species[6] on non-food-crop land, and forest wood wastes[7] become preferred sources of biomass.

Most biofuels from animal sources (tallow, whale oil, lipo-suctioned human body fat[8]) are more costly to produce, more valuable or more protected than those from vegetable sources. There are too many vegetable oil sources to list. Rapeseed (rapa, colza - all *Brassica napus*

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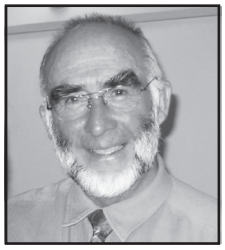

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var. oleifera) oil or CANOLA (CANadian Oil, Low Acid) has become the preferred feedstock, particularly in Europe, and particularly for conversion to biodiesel by base-catalysed transesterification, producing monoalkyl esters. 'Biodiesel' is not (fossil-petroleum-derived) diesel, but a biofuel with recognised specifications[9] that is miscible with diesel or can run alone in compression-ignition engines.

Babassu palm (*Orbignya martiana*, *Orbignya oleifera*) and jatropha (*Jatropha curcas/curcus*, Barbados nut, physic nut) are most often quoted in recent years as promising new sources of vegetal oil, but sunflower, coconut, soya bean and other oils are also mentioned. There is controversy over babassu oil because deforestation is occurring to provide plantation culture. And while jatropha is indeed able to grow (e.g. in India, Africa and South America) on very poor land, it is also a poisonous shrub which has been made a 'declared plant' (not a prohibited import, but sale or distribution might be illegal) in Western Australia[10]. Agronomic history tells us that plants which are 'able to grow' on poor land often turn into 'crops' which grow even better on good, arable land! What is already happening with babassu could also happen with jatropha. "Brazil and Indonesia were jointly responsible for two-thirds of the global net loss in forest from 2000 to 2005[11]." Part of this was due to rapid development of biofuel crops.

The state-of-play in New Zealand 2008

Bioethanol from whey, a waste product of the dairy industry[12], is produced by the Fonterra Cooperative Group and marketed as 10% blends with both 95 octane petrol ('Gull Force 10') and 91 octane petrol ('Gull Regular Plus') by Gull Petroleum. This is the only sustainable, energy-efficient, commercially attractive and sourced-in-New Zealand option of significant volume in place in this country in 2008. A number of firms have for some time been producing biodiesel from waste cooking oil, or from tallow. Waste cooking oil is a very small resource compared to total diesel use and will not be a resource of significant volume at any time in the future. Tallow is available in much greater quantities[13] and several firms (e.g. Biodiesel Oils; EcoDiesel) have plans to increase present production with a view to meeting the Government's Sales Obligation (see Policy Environment 2008, below) of about 75 million litres per annum to be blended with diesel by 2012. But tallow is a valuable commodity for other purposes, including export for use as a constituent of soap and food products. During Environment Canterbury's tallow/biodiesel bus trial[14], the price of tallow increased from $570 per tonne at the start in September 2006 to a peak of $1300 and currently $1000 in October 2008.

Biodiesel from rapeseed oil is now in commercial development by Biodiesel New Zealand[15], a subsidiary of the state-owned enterprise, Solid Energy New Zealand. There has been both support from potential growers[16] and criticism from science commentators[17], farmer groups[18] and others (including myself[19]) of this option. Despite some poor crop results in the first season[20], the website of Biodiesel New Zealand advises[21] of "plans to increase its production to 70 million litres of biodiesel a year, or around 2% of the country's total diesel use and more than half[22] of the Government's 2012 target for biofuels use." In its "Horticulture and Arable Monitoring Report for 2007", the Ministry of Agriculture and Fisheries summarised[23]: "The potential for the biofuel industry to expand into New Zealand is causing both optimism and concern in the arable industry. On the one hand, global biofuel demand is raising all crop prices globally. Even where a crop is not directly related (for example, vegetable seeds), the bargaining power for New Zealand is increased as European farmers find cereals or oilseeds easier to grow than vegetables for seed production, thus increasing the opportunity for New Zealand vegetable seed exports. However, for those farmers and industry involved in the production of specialist brassica seeds, the prospect of canola production in New Zealand is seen as a threat to their industry. Separation distances must be maintained between canola and brassica crops, which may cross-pollinate; otherwise, seed of sufficient purity is not produced. If large areas of canola crops are grown, this will severely reduce the potential area available for brassica seed crop production. For some farmers, particularly those who run less-intensive mixed livestock and crop systems, the prospect of growing canola as a new spring crop option is very attractive in an environment where there are few profitable options."

Policy Environment 2008

The most relevant current policy is the 'Biofuels Sales Obligation'. In April 2008, the Parliamentary Commissioner for the Environment recommended to a select committee of Parliament that the relevant Bill should not proceed to become legislation[24]. However, in spite of a minority view in opposition (attached to the select committee report) from the National Party members of the committee, it was enshrined in legislation effective[25] October 2008. The Biofuel Sales

Obligation obliges firms (such as the major oil companies) which import petrol or diesel, or obtain them from any New Zealand manufacturer, to have a percentage of the energy content of the combined petrol and diesel sold by them to be biofuel. The percentage starts at 0.5 percent and increases to 2.5 percent by 2012. At present, only biodiesel and bioethanol are specifically included as 'obligation fuels' for climate change greenhouse gas calculations.

The climate change policies are also relevant to biofuels use; most relevant is the 'Emissions Trading Scheme'. This was included by amendment in September 2008 in the Climate Change Response Act 2002 No. 40[26]. The 'liquid fossil fuels' business sector is required to monitor emissions of greenhouse gases from 1 January 2011, with the first annual report due March 2012. All businesses which supply more than 50 000 litres annually must self-assess emissions

in carbon dioxide equivalent and surrender emission units ('carbon credits') annually to the government. An emission unit is equivalent to one tonne of carbon dioxide (or its equivalent in other greenhouse gases) that would otherwise have been emitted into the atmosphere. They are effectively tradable allowances for greenhouse gas emissions. As a country with targets under the Kyoto Protocol, New Zealand must hold sufficient emission units to match its actual emissions during the first commitment period of the Protocol, 2008-2012.

The central government allocated emission units by tender rounds in 2003 and 2004 to qualifying projects which would reduce equivalent carbon dioxide emissions by a minimum of 10 000 tonnes annually in the first Kyoto Protocol commitment period. That minimum would need 750 000 litres of diesel or 875 000 litres of petrol to be removed annually from emitting by a project, compared to business as usual. Nearly 10 million emission units were allocated in the two rounds[27] but nearly all were for small hydro, wind power, landfill gas or geothermal projects; there was just one biofuel project: 20 000 units for "manufacture and sale of wood pellets". Separately, emission units have also been awarded to forestry projects through the Permanent Forest Sink Initiative[28]. Under present policy, only carbon sequestered by 'forest species' (trees capable of reaching five metres in height at maturity in the place they are growing) is eligible to be considered for allocation of emissions units.[29]

Further relevant policies or strategies are contained in the New Zealand Energy Strategy to 2050 (issued 2007), the New Zealand Transport Strategy 2008 and the New Zealand Energy Efficiency and Conservation Strategy (issued 2007).

Research Environment

There was a spurt of biofuels research activity in New Zealand following the 1970s 'oil price shocks', much of it funded by two long-since-defunct agencies: the Liquid Fuels Trust Board and the New Zealand Energy Research and Development Committee. When fossil oil prices reduced, laboratory work stopped, pilot plants closed, reports went on to shelves to gather dust and business as usual resumed for two or three decades. Currently, most central government funding is committed through the Foundation for Research, Science and Technology (FRST). There is from 2008 a 'Low Carbon Energy Technologies (LCET)' scheme which specifically targets research related to the scale-up and demonstration of existing research on second generation biofuels, other low-carbon liquid biofuels and low-carbon energy technologies. Other biofuels research is currently funded by FRST in the 'Infrastructure and Resources' and 'Optimising Physical Resource Use and Infrastructure' portfolios. The main FRST 2008 research round allocated 9%, or $40 million, of all contestable funding to biofuels research. Many of the crown research institutes and universities have current biofuels research funded by FRST.

Much recent near-market research and development has been funded by both onshore and offshore commercial enterprises. By the nature of these entrepreneurial activities, it is often difficult to obtain information and to distinguish real research progress from public relations hype aimed at potential investors. There are also many dedicated, and sometimes genuinely innovative, individuals and small companies who are pursuing their own 'solutions' to New Zealand's medium-term transport fuel problems. Much of this work is necessarily self-financed, as some kind of track record is usually required before central government, other funding agencies or commercial investors will take an interest.

International Initiatives

There has been an unfortunate and premature over-enthusiasm for biofuels development, particularly in USA and Europe, in advance of the availability of appropriate and sustainable 'second generation' feedstocks and technologies. Politicians have jumped on bandwagons before properly understanding what their horses are eating and what music the band is playing. The result has been ill-conceived support schemes and the need to re-visit incentives and regulations[11,30]. There is now serious interest in second generation biofuels development by multi-country blocks (like the European Union), national governments and large corporations.

In the USA the Energy Independence and Security Act of 2007 requires fuel producers to use at least 136 gigalitres (10^9) of biofuel annually by 2022. This represents about five times previously required levels. In Europe, 2.6% of the energy content of all the fuels used in road transport is already from biofuels[31]. The target set by the 2004 EU directive on biofuels is 5.75% by 2010. Both production increases and increased imports will be necessary, in spite of the misgivings and problems now in focus[11,32].

In Australia, the biofuels industry is still quite small, supplying less than 0.5 per cent of transport fuel[33]. Biodiesel and ethanol are made from canola oil, cotton seed oil, wastes and co-products of food production such as C-molasses, waste starch (from flour milling), and tallow. The major Federal policy set by the previous administration in 2005 was a 350 megalitre per annum target by 2010. The previous administration had resisted having obligatory biofuels, but there had been support grants for biodiesel and bioethanol production and a remission of excise scheme. The post-2007 Federal Government is still developing biofuels policy.

The aviation industry has constraints and problems additional to those faced by land-based transport. They not only need a convenient, compact density and high energy fuel, as for other transport, but one of low flammability, which does not freeze or otherwise thicken at high altitude, is not hygroscopic, meets emission standards and can be made available all around the world to tight specifications. From 2006, for the first time, fuels became the largest component of USA airlines' operating costs. A Commercial Aviation Alternative Fuel Initiative (CAAFI) was set up by industry authorities and associations[34] in October 2006. An indication of their short-term and medium-term intentions can be gleaned from a recent statement[35] by CAAFI's Executive Director: "CAAFI is currently refining roadmaps …(for)… environmentally friendly (i.e. with emissions sequestration) coal/biomass to liquid (CBTL) synthetic blends produced by the Fischer Tropsch process, as well as hastening the potential of environmentally friendly HRJ[36] fuels (derived from plants such as jatropha) and biofuels from algae and other feedstocks."

Air New Zealand is a partner with Boeing Corporation and Rolls Royce in a proposed demonstration flight of a

Boeing 747-400 "in the second half of 2008" which will use Bio-jet fuel incorporating "second-generation methodologies relative to sustainable feedstock source selection and fuel processing ." Virgin Atlantic, Boeing, GE Aviation and Imperium Renewables had already flown a demonstration flight in February 2008 which used a small amount[19] of babassu and coconut oil derived jet fuel in a blend. Air New Zealand, Virgin Atlantic and Boeing Corporation are also 'Platinum Members' (along with UOP-Honeywell and USA legal advice firm Wilson Sonsini Goodrich & Rosati) of the Algal Biomass Association.[39]

The 2008 NZIAHS Biofuels Forum: Content

There were five papers presented at the Biofuels Forum organised by the Canterbury Branch of NZIAHS and held at Lincoln University on 27 August 2008. The written versions of those papers[1,6,7,15,24] are published in *AgScience* Feb 2009. Steve Wratten's paper[1] notes some of the problems of first generation biofuels and how they might occur in New Zealand. He outlines a six-year programme of research starting up now, funded by FRST and supported by Chevron NZ, Biodiesel NZ/Solid Energy, Ngai Tahu and others. This programme has worthy aims for novel and more sustainable production of biodiesel, with economic and ecological advantages. "In 2008, we are facing new energy crises relating to global warming, 'peak oil', rapid increases in world population and individual wealth of some sectors of society and exceptional increases in oil prices, impacting on food costs" states Professor Wratten. He also wonders if "people in the richer nations should consider going on an 'energy diet'." In the context of transport fuels, this is not a matter of choice it is an inevitable consequence of our present state and the physical limits of rates of change.

The paper[24] by Jan Wright [co-author Caren Schroder] reviews her April 2008 decision, as Parliamentary Commissioner for the Environment, to recommend "to a select committee of Parliament that the Biofuel Bill not proceed to become legislation." Her opposition was based on evidence that the Bill was likely to fail in its two aims: to "reduce our net carbon dioxide emissions and increase the security of energy supply, particularly for transport." Amendments which became part of the 'biofuels obligation'

and 'emissions trading scheme' legislation (see **Policy Environment 2008**, above) should overcome some of Dr Wright's objections. A valid concern remains "about the practicality of implementing and enforcing sustainability standards, particularly overseas". Also a valid concern is the "looming gap between supply and demand", which needs to be urgently addressed on both sides of the gap. Biofuels

are part of future transport fuel supply, in particular, but Dr Wright also points out that they are a relatively small part of the overall energy system and need to be considered alongside other significant aspects, such as electricity and a plentiful supply of wood in New Zealand.

The third paper[15] primarily focussed on first generation biofuel was that by David Geary, describing progress with implementation of commercial production of biodiesel from rapeseed. Biodiesel NZ and parent Solid Energy NZ must have examined both the technical and commercial aspects of this venture before committing to the substantial development costs. It nevertheless remains first generation in both feedstock and technology, with some of the well-documented defects that implies. "Globally, oilseed rape is ranked as the third most important edible oil crop after soybean and palm." As already discussed here, the difference between on-farm production cost and farm-gate value is a major driver of what farmers grow and "for some farmers, particularly those who run less-intensive mixed livestock and crop systems, the prospect of growing canola as a new spring crop option is very attractive in an environment where there are few profitable options"[23]. Mr Geary's paper records Solid Energy's "commitment to help New Zealand's transition to sustainable and renewable energy sources." The Climate Change Response Act 2002 No. 40[26] already includes fuel derived from "rotational oilseed crops grown not more than 12 months in any 24 month period on the same land or as otherwise specified in the Order in Council" as obligation fuel. Notwithstanding the problems (see **The state-of-play in New Zealand 2008**, above), biodiesel from rapeseed and tallow are the only home-grown biofuels which will be available in significant quantities for blending with diesel in the next few years to help meet biofuel sales obligations from New Zealand sources.

The two remaining papers[6,7] at the Forum consider second generation options from wood feedstocks. Jim Watson[6] makes clear his view "that energy can only be considered truly renewable if it is produced by effectively harnessing the power of natural resources or if it results from converting replenishable biomass into gases or biofuels, without threatening the food supply or harming the environment." For transport biofuels: "We can do it poorly, with short-run approaches which have no potential to scale and produce an adverse environmental impact; or we can do it properly - with long-term solutions that can meet our biofuel and environmental needs." "None of the "food/feed crop" based biofuels (corn or sugar based) or biodiesel sources (soy, vegetable oils) comes close" to the economic and environmental targets Dr Watson considers we must meet. Bioethanol from lignocellulosic material is the option that he and colleagues have chosen to pursue; it requires pre-treatment and hydrolysis prior to fermentation, so reducing the economic and energy costs of these processes is crucial. If the processes can preserve valuable lignin and hemicelluloses as by-products, so much the better. His paper does not discuss the possible use of coppicing shrub willow (e.g. crosses from *Salix viminalis*) on marginal land as a purpose-grown feedstock, but colleagues of Dr Watson have done that in other publications.[40] In addition to information on process technology and more general comments on biofuel development in New Zealand, the paper has some cogent comments on the difficulties of funding near-market research and development in New Zealand.

The final paper[7] considered, by Piers Maclaren, sings the praises of forest wood as not just a natural solar panel, but a storage battery to boot. "Trees accumulate and retain the energy in sunlight for decades, or until the energy is required for use." And they can do this without competing with agriculture for land. Mr Maclaren explains 'forest' and 'stand' differences in terms of carbon balance and explains that "a steady-state forest may supply greenhouse-neutral fuels continuously and indefinitely." So while wood as a biofuel is as old as humankind, it has a future as a feedstock for second generation biofuels, including those for transport. The paper provides a balanced view of alternative uses of forest wood, including waste wood, and briefly mentions a few of the technologies available for converting wood to liquid biofuels. A recent National Science Foundation (USA) report[41] points out that lignocellulosic biomass can now be produced in the USA at costs that are about US$15 per barrel of oil energy equivalent lower than the price of crude oil. Enough could be sustainably produced on USA agriculture and forestry land to equal the energy content of 60 % of the current USA fossil oil consumption. "The key bottleneck for lignocellulosic-derived biofuels is the lack of technology for the efficient conversion of biomass into liquid fuels." A recent report from Scion in New Zealand[42] suggests that bioethanol from plantation feedstock is not yet cost-competitive, but could be by 2020. It would take about 2.7 million hectares (34% of the available low to medium quality grazing land) to produce the foreseen[42] 2040 total transport fuel need (excluding air and sea transport).

The 2008 NZIAHS Biofuels Forum: Missing Information

The most significant second generation feedstock not covered in the Forum papers was microalgae. This was surprising for several reasons: microalgae are phenomenal biomass producers[19]; they are both the oldest (fossil oil) and among the most truly second generation (not competing with food production, sustainable) biofuel feedstocks; they have been internationally recognised as a major player in future biofuel production; and there has been quite a lot of publicity in New Zealand about algal biofuel. As this paper is intended to be an even-handed review, and as I have been an advocate of 'algae to oil' for several years, it is appropriate that I should simply quote from a recent, reputable, joint European/USA report[43]: "The technical potential of micro-algae for greenhouse gas abatement has been recognised for many years, given their ability to use carbon dioxide and the possibility of their achieving higher productivities than land-based crops. Biofuel production from these marine resources, whether use of biomass or the potential of some species to produce high levels of oil, is now an increasing discussion topic. There are multiple claims in this sector but the use of micro-algae as an energy production system is likely to have to be combined with waste water treatment and co-production of high value products for an economic process to be achieved. These current biofuel discussions illustrate two issues. First, the potential broad utility of these organisms that are capable of multiple products, ranging from energy, chemicals and materials to applications in carbon sequestration and wastewater remediation. Second, the need for a robust evidence base of factual information to validate decisions for the strategic development of algae and to counter those claims made on a solely speculative basis to support commercial investment." The UK Carbon Trust, funded by the UK Government, announced on 23 October 2008 an 'Algae Biofuels Challenge' with M£20-30 funding, to carry out Research and Development into open-pond algae selection, growth and harvesting.

New Zealand can claim to be among world leaders in some aspects of algae biofuel developments, both in scientific and commercial aspects. Research groups in NIWA[44], Cawthron Institute[45], Landcare Research[46], the University of Canterbury[47] and Massey University[48] are studying algal biomass, including for biofuels. Two commercial firms are claiming major breakthroughs in relevant technology. Aquaflow Bionomic announced[49] on 11 September 2008 that it had "produced the first samples of green-crude from its proprietary processes" which, in essence, "has the same origins as traditional oil reserves". Aquaflow had previously been more concerned with converting the oil fraction of algae harvested from Marlborough municipal wastewater ponds into biodiesel. They announced on 30 October 2008 that they had signed a Memorandum of Understanding with USA company UOP (Honeywell) to use "existing UOP processes to produce renewable fuel" and to "develop a carbon dioxide sequestration storage model for Aquaflow's algal oil production facilities." Solvent Rescue in Christchurch[50] and Rayner Engineering in Invercargill[51] (together Solray Energy) revealed on 18 September 2008 that they had completed a patented "super-critical water reactor" under development since 2003. Students and colleagues under the direction of Dr Chris Bathurst of Solvent Rescue had identified algae as a likely biofuel feedstock in 2002 and produced biodiesel from algae at the Christchurch Wastewater Treatment Plant in 2003.

Other second generation technologies were either mentioned only in passing or in discussion at the Forum. The largest research grant in the August 2008 FRST Low Carbon Energy Technologies funding was of $12 million to Lanzatech[52] to develop a second-generation "low-carbon petrol" biofuel from industrial flue gas waste. Six projects in the August 2008 FRST Infrastructure and Resources investment round were also related to biofuel feedstocks and technologies not covered at the Forum.

Promising Biofuel Options for New Zealand 2009-2013

To have promise for implementation in New Zealand in the next few years, biofuels should satisfy at least these criteria:

- Fuel properties allowing blends which meet appropriate standards with current fossil oil transport fuels and allow immediate use in the current vehicle fleet
- Feedstock availability sufficient to provide fuel in quantities relevant immediately to the biofuel sales obligation and in greater quantities soon after
- Sustainability, at least satisfying the principles related to greenhouse gas reduction, not competing with food crops and not reducing biodiversity or conservation values, as set out in the 2008 update of the Energy (Fuels, Levies, and References) Act 1989
- Commercial viability

Appropriate life cycle assessed energy performance

A second tier is of 'desirable' criteria:

- New Zealand feedstock and technology rights
- Clean technology of high New Zealand content
- Secondary benefits e.g. waste product use or environmental cleanup
- Useful and valuable co-products or by-products, or being itself a co-product or by-product of an economically and environmentally valuable product
- Intellectual property, technology or product export potential
- Contributing to progress towards living within transport energy 'flows' (not mining 'stocks')
- Contributing positively (at least potentially) to the overall New Zealand energy system

There has recently been a small number of single feedstock and technology combinations subjected to different life cycle assessment procedures[53], and a small number of different feedstock and technology combinations subjected to a single life cycle assessment procedure[42]. But there has not (to my knowledge) been in New Zealand a single life cycle assessment procedure applied to a reasonably large number of feedstock and technology options. (A comprehensive 'well-to-wheels' energy and greenhouse gas emission study was carried out in Europe in 2003 and updated in 2006[54].) For that reason, and because it would be a pity to end a review of this nature without picking a few winners, the rest of this section must be understood to be my opinions, unsupported by the kind of analyses I would like to have seen performed.

Bioethanol as a by-product of the dairy industry already meets most criteria in the first set above, some in the second set, and has promise in that production can readily be expanded to provide "greater quantities soon after" sales obligation quantities for petrol are met. For diesel, and for alternatives to dairy bioethanol for petrol, it is easier to identify which options are NOT promising than those which ARE. Comment has already been made above about the defects of waste cooking oil, tallow and rapeseed as feedstocks for biodiesel production. Coal gasification and liquid fuels synthesis by the Fischer-Tropsch process would be likely to fail the sustainability (greenhouse gas reduction) and energy performance criteria. Any biofuel option involving hydrogen as the transportable fuel immediately fails the very first criterion.

Bioethanol from cane sugar imported from Brazil does not meet many of the 'desirable' criteria involving New Zealand benefits. It seems likely to meet most of the first set of criteria, although there will probably be argument about how well it meets the sustainability principles[55]. It promises to be valuable for petrol blends early in the 2009-2013 quintade, particularly if whey bioethanol production falls short of demand. In spite of the supply and sustainability defects already referred to, biodiesel from tallow, palm oil and jatropha could well play a similar role for diesel blends. It will be interesting to see how sustainability criteria are applied to imported supplies.

Towards the end of the quintade, I see promise in algae feedstock with super-critical water reaction technology and associated wastewater cleanup[56] providing oil for whichever transport fuel users place most value on this combination's particular advantages - quite possibly aviation jet fuel users. With similar timing, forest waste or purpose grown wood feedstocks should start providing multiple co-products, including transport biofuel, via one of the routes now in active development[42].

So are biofuels the future, or a folly? They are no folly, although there have been some unwise policies put in place, with undesirable outcomes in the past and present, and there are some foolish claims still being made. The positive view is of some very promising second generation options and the advanced state of development of some of them in New Zealand. "Biofuels are neither good nor bad. They have an important transitional role in New Zealand's transport fuel future.[19]"

Acknowledgements

The NZIAHS Canterbury Branch Committee and Biofuels Forum organisers invited me to chair the Forum. Subsequently, they requested this summary paper and review. NZIAHS Secretariat and AgScience Journal staff gave me a free hand and much assistance. Three colleagues knowledgeable about biofuels[57] kindly reviewed the draft article.

End Notes

[1] Wratten SD "Prospects for environmentally-sound biodiesel crops", this issue.

[2] Some writers divide this as: natural byproducts or waste products (2nd generation); purpose-grown biomass, like algae, switch grass, shrub willow (3rd generation)

[3] Najafpour, GD, "Industrial Microbiology", Chapter 1 in "Biochemical Engineering and Biotechnology", Elsevier, 2007.

[4] "Ford Predicts Fuel from Vegetation," *New York Times*, Sept. 20, 1925, p. 24

[5] Nimmo-Bell and Co., "Rising food prices and biofuels", Report to EECA and MAF Policy, September 2008.

[6] Watson JD, "Biofuel Opportunities", this issue.

[7] MacLaren P, "Biofuels from forestry: A forest scientist's perspective", this issue.

[8] "Mad sailor Peter Bethune not a nutcase", *NZ Herald* 8 April 2006

[9] E.g. EN14214 in Europe; ASTM D6751 in USA, NZS 7500: 2005 in New Zealand.

[10] List available at http://www.agric.wa.gov.au/content/PW/WEED/PERMITTED_PROHIBITED.HTM , sighted 22 October 2008.

[11] "The Gallagher Review of the indirect effects of biofuels production", Renewable Fuels Agency (UK), July 2008

[12] It would thus be 'second generation' to the writers mentioned in Note 2.

[13] About 150 000 tonnes per year as a byproduct of the meat industry, converting to about 150 Ml of biodiesel.

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