Biodiesel and Renewable Fuels

Best Practice and Policy Implications

A report for

By Caroline Brown

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Foreword by Barbara Brown

Caroline has had a passion for the environment from an early age. When she had the opportunity to apply for a Nuffield Scholarship her immediate response was, “I can look at Biofuels”. Her concern being that our overuse of Fossil Fuels to maintain our western standard of living was creating a problem that would cause great suffering for the next generation.

On being awarded the scholarship from Nuffield Australia and GRDC in particular, she set about scouring the world to find the countries and the people who were diligently focusing their attention on best practice in renewable energy and in particular biofuels. Her trip brought her into contact with inspiring people and Governments with a passion for the preservation of the earth as we know it. She gained a wealth of information regarding renewable material not only for energy requirements and also for replacing petroleum based chemicals for industrial purposes as well. As her report shows, with innovation we can maintain our lifestyle and reduce our dependence on fossil fuels. To achieve this goal our Government needs to direct serious incentives towards the scientific endeavors of those working in the renewable energy sector and away from the fossil fuel industry.

She has been disappointed with Australian political attitude that our immediate economy comes before the health and well being of present and future generations. Australians who used to pride themselves on being “clean and green” are being left behind in the world awakening that we are destroying our planet by using fossil fuels.

I recommend her report to you and hope that, along with the current agitation about Climate Change, it will encourage positive reduction in the use of Fossil Fuels and the increased use of biofuels and other renewable energy sources by Australians and the World in general.

Barbara Brown.

Abbreviations, definitions and conversions

Biodiesel density	0.88 kg/l
1.0 US bushel	= 56 lb, 25 kg (corn or sorghum) = 60 lb, 27 kg (wheat or soybeans) = 40 lb, 18 kg (barley) = 0.0352 m^3
Barrel of oil equivalent (boe)	approx. 6.1 GJ (5.8 million Btu), equivalent to 1,700 kWh. "Petroleum barrel" is a liquid measure equal to 42 U.S. gallons (35 Imperial gallons or 159 liters); about 7.2 barrels oil are equivalent to one tonne of oil (metric) = 42-45 GJ.
biodiesel	Chemically, most biodiesel consists of methyl esters instead of the alkanes and aromatic hydrocarbons of petroleum derived diesel. However, biodiesel has combustion properties very similar to petrodiesel, including combustion energy and cetane ratings. Biodiesel is commonly derived from used cooking fat, tallow or vegetable oil.
biofuel	liquid or gas transportation fuel derived from biomass
British Thermal Unit (BTU)	Amount of heat needed to raise one pound of water by 1º Fahrenheit
BTL	Biomass to Liquid
diesel	A specific fraction of distillate of fuel oil (mostly petroleum). The average chemical formula for common diesel fuel is $C_{12}H_{26}$, ranging from approx. $C_{10}H_{22}$ to $C_{15}H_{32}$
Energy content of **agricultural residues** (range due to moisture content)	10-17 GJ/t (4,300-7,300 Btu/lb)

Kilowatt hour (kWh)	A unit of energy of work equal to 1000 watt-hours. The basic measure of electricity generation or use. A 100 watt bulb burning for 1 hour uses 1 kilowatt hour
kWe	One thousand watts of electric capacity
Ktoe	1000t oil equivalent
Metric tonne **biodiesel**	37.8 GJ (33.3 - 35.7 MJ/liter)
Petro-diesel petro-diesel density (average)	130,500 Btu/gallon (36.4 MJ/liter or 42.8 GJ/t) = 0.84 g/ml (= metric tonnes/m^3)
U.S. gallon	3.79 liter = 0.833 Imperial gallon

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Executive Summary

The biofuel industry is emerging in the world as an opportunity for both the environment and economies of developed and developing countries. Global warming, increasing dependence on dwindling localised supplies of oil and political turmoil caused by competition to secure these resources are all factors that set the stage for renewable energy on a global scale. On a local scale, renewable energy is an opportunity for farmers to increase wealth (through industry and land use competition) and status as the major contributors to a sustainable future.

Unfortunately, the Australian Government has been slow to adopt policy conducive to renewable energy developments (including biofuels), citing the poor economic viability of such an industry to be a detriment to this country as a whole. This scholarship has given me the opportunity to travel in countries with governments that had the foresight to financially assist in developing the science behind extracting energy from photosynthetic material and to see the rewards this now provides for their economies. These rewards are evident in job creation, ownership of valuable intellectual property and increasing competitiveness of renewable fuels against the entrenched use of fossil energy. Much of the wealth created through this new industry remains in rural areas which has positive consequences for rural communities and the governments that are under pressure to reduce subsidised agriculture in the era of free trade agreements and standards scrutinised by the World Trade Organisation (WTO).

Aims and Objectives

My aims and objectives in researching and writing this report were as follows:

1. My main objective was to gain a good perspective of the emerging biofuels industry with a view to determining the areas that farmers' investments are likely to have the best long term security – ***opportunities for Australian farmers***.

2. Identify any benefits / detriments that would flow to Australian farmers as a result of the international economies encouraging biofuel production in their own countries ***Benefits/Detriments.***

3. Identify which political strategies were effective in encouraging private investment into the industry and which should be avoided – ***Political strategy***.

Findings and Recommendations

1. *Opportunities for Australian Farmers:* In this global economy, renewable energy (including biofuel) is here to stay. Australia's huge coal resource seems to be an incentive for the development of "clean coal" technology (including coal to liquid for transportation energy). Although this will certainly play a part in supplying ever increasing energy demands, renewable energy from agriculturally supplied resources has potential to play a significant role in energy supply. Coal supply, although abundant in certain parts of the globe, is finite and the technology needed to convert coal to clean energy is far from proven and carries many risks (not discussed in this paper). Government support for technology based on non-renewable resources In preference to renewable leaves Australia standing alone from the rest of the world and is a well advertised threat to our 'clean green' image and the premium this brings to our export products.

   The technology required to harness energy from photosynthetic materials (i.e. the creation of biofuel) is proven, rapidly improving and is favored by the broader community. Having said this, the aim of all research is to extract as much useable energy as possible from any material, with the minimal expense of energy. This concept extends to the need to maximise energy production per unit area of land in order to make any significant contribution to global transportation energy requirements and reduce the problem of land use competition for food production.

   Energy efficient production is imperative and, in my opinion, the long term future of biofuel production lies with new 'second generation' technologies such as biomass to liquid ('BTL') and cellulosic ethanol. BTL and the production of cellulosic ethanol require enormous investments, beyond the reach of most farming entities (the 2005 estimated set up cost of BTL is in the order of AU$750 million). Biodiesel production from first generation oilseed crops is a stepping stone in the industry.

   The Farming industry is in an excellent position to capitalise on ownership of the biomass feedstock – that is, within the bounds of the Trade Practices Act, owners/producers of the primary feedstock, growers should co-ordinate their efforts to gain best possible exposure to markets and prices.

The development of second generation technologies does not render existing investments unviable, however, it does reduce the lifespan thus necessary payback time of the investment (unless the major feedstock is otherwise a waste produce for example, used cooking oil). The motivation for small scale biodiesel plants should be examined carefully as a competitive advantage is imperative for the long term viability of such a venture. If the environment is the sole motivating factor, this should be made clear to potential investors.

This paper also discusses the potential for algal supply of industrial oil and its fit in Australian industry.

One of the most outstanding opportunities for the agricultural industry is the production niche chemicals from agricultural crops and residues. The feasibility of many of these possibilities is not yet determined; however, if the demand for biobased products continues to increase and the research continues, many of these possibilities will become commercial realities. In the current market, biogreases provide and immediate opportunity for farmers. The report discusses these opportunities and looks at electricity and heat production from agricultural wastes which would also be viable given suitable policy from government.

2. *Benefits/Detriments* - In terms of advantages emerging for Australian farmers as a direct result of subsidised energy production in other countries, Australia benefits through less competition from the over supply of commodities such as wheat. It is now evident that the surge in energy crops in countries such as America and Europe is having a positive effect on our wheat and canola prices as a direct result of land use substitution in America and the EU. There is also the potential opportunity to trade biomass to these countries which may not have the means to efficiently produce enough biomass at an acceptable price for the energy market. It remains to be seen if Australia can produce energy crops efficiently enough to supply these international markets. It may also be necessary for tax subsidies in these countries to apply to imported products. However, this seems unlikely since measures are now being taken to limit this effective subsidy for foreign production.

3 *Political strategies* - Policy creation is imperative for the establishment of the industry. The most effective policies that I observed were the creation of an automatic market for biofuel (via a mandate) with the onus on the petroleum companies to meet this mandate and strict environmental emission standards. These, in the longer term would appear to be much more effective than tax benefits (which are also unfavorable from a Government's point of view due to a direct reduction in revenue). This report also highlights the subsidy discrepancy between the petroleum and renewable fuel industry and suggests that funding for the renewable industry could easily be transferred from the petroleum industry.

4. *Findings & Recommendations*: Biofuels from agricultural resources will only ever be a part of the whole energy equation. The size of that "part" will ultimately depend on, effective and consistent policy, efficiency of production and processing, co-operation between farmers, environmentalists and the petroleum industry and finally, demand from the broader community driven by environmental concerns.

The agricultural industry stands to gain from the establishment of a renewable fuels industry by:

- Land use competition driving up the price of traditional commodities (for example, wheat)
- Opportunity for new crop production (biomass) giving greater diversity in agronomy and farm income
- Opportunity to take part in carbon trading (diversified farm income)
- Production of crops for emerging bio-chemical markets to replace petroleum based chemicals
- New markets for materials that are currently considered "waste products" and incur costs to be treated / disposed of
- Trade opportunities with:
  - Trade directly in biomass for energy production
  - Trade of traditional commodities (e.g. wheat and beef) into areas that are favoring energy production at the expense of these products
- Opportunity for investment into renewable energy technologies which have intellectual property value
- Enhance / preserve Australia's "clean green" image
- Reduction of the environmental damage caused by agricultural practice by replacing fossil sourced energy with renewable energy

Recommendations (progress and research):

Based on observations made during my scholarship travels, I believe the following areas of research need to be pursued if farmers are to gain benefits from a Biofuel Industry.

- Research into biomass production and the Australian climates and soils that are best suited for biomass production.
- Research into oilseed crops remain focused on high value market requirements (i.e. human consumption or biogreases rather than biodiesel)
- Research into the extraction techniques and feasibility of process to isolate industrial chemicals from agricultural products
- Investigation into the viability of algae production on the North West coast of Australia in association with the carbon dioxide emissions from the natural gas facilities.
- Early establishment of co-operative structures that meet the Australian Competition and Consumer Commission (ACCC) / Trade Practices Act requirements and place farmers in a position to best negotiate the value of biomass products for energy production.
- Investment into broader consumer education as to the environmental benefits (i.e. emissions) of biofuels and the benefits to the vehicle engine (i.e. lubricity of biodiesel) to encourage demand for the product
- Stronger lobbying to the Australian government for
    - more even support in comparison to the petroleum industry
    - tougher emission standards

Introduction

The biofuels industry is an opportunity for biomass providers, biofuel producers, the automotive industry and consumers of liquid fuels. This report reviews current international practice in the development of technical processes involved in the production of biofuels, the raw materials used in the course of production and the policies adopted by various developed and developing nations to support the industry. The report also considers the use of carbon credits, opportunities open to Australian primary producers to tap into the biofuels industry and the legislative environment necessary for the development of a successful Australian Biofuels Industry.

In my view the key requirement for a successful Australian biofuels industry is a sharp change in current policy. The prevailing view amongst Australian policy makers appears to be that as Australia has a large fossil fuel resource, the investment required to change from fossil fuels to biofuels or renewable energy resources outweighs the medium term benefits of such a shift. As such, Australian legislation and policies do not foster the industry or set goals for future levels of biofuel consumption comparative to other developed nations. A change in this 'laissez faire' attitude towards the renewable fuel industry will require recognition by politicians, their advisers and the general public of the reality and likely impact of global warming and an evaluation in real terms of the present cost to the future generations of failure to act to reduce fossil fuel emissions.

Most developed countries aim to ensure that a large proportion of their transportation fuel is sourced from clean and efficient biofuels within the next 20 years. While Australia has set a non-mandatory target of 350 million litre inclusion of biofuel by the year 2010 (less than 1% of current transportation fuel use), the EU vision is for one quarter of its transportation fuels to be biofuel provided by the European Biofuel Industry by 2030. In America, the Bush administration has set the goal of replacing 75% of oil imports from the Middle East with renewables[1] by the year 2025 and has a mandate for 7.5 billion litres of biofuel by 2012.[2]

[1] For the purpose of this paper, "renewables" is defined as energy harnessed from non-fossil sources. It also excludes nuclear power.
[2] One lobby "25 x 25" would take this further to target 25% of all of the US energy consumed to be supplied by renewables by the year 2025. The 75% imported oil replacement is in line with this target since most of the oil supplied to the U.S. is from external sources.

Similarly, developing countries aim to take advantage of trade opportunities emerging from this new industry. The Indian government is supporting a project to plant half of the arid region 'wasteland' (which equates to about 25 million hectares) to oil producing crops such as pongamia and jatropha. The aim of this project is to provide 20% oil sufficiency. South America has been the world's leader in production and use of ethanol for more than 25 years reducing its dependence on price volatility and supply concerns.

In keeping with the ambitious targets of these countries new technologies are being developed to produce biofuels in a more energy and cost efficient way from a wider range of biomass feedstocks. Technologies are being developed to encompass economic[3], environmental[4] and social[5] expectations of today.

[3] production capacity and operating costs
[4] carbon dioxide performance, energy balance and effect of biomass production
[5] competition with food production and job creation

Focus on the European Union

Current biofuel production levels in the EU

In 2004 the EU produced 2040 kilo-tonnes oil equivalent (ktoe) of biofuel. This equates to about 0.7% of the transportation fuel market in the EU. Of this, Germany, France and Italy produced nearly 2 million metric tonnes (Mt) as biodiesel from rapeseed between them.

Future biofuel production in the EU – how they plan to meet their 2030 target

The European Commission estimates that currently the total sustainable worldwide biomass energy potential is about 104 EJ/a (EJ = 10^{18}) which is about 30% of total global energy consumption (2004)[6]. In order to meet the aim of 25% renewable fuel by 2030, feedstock will be mainly in the form of biomass[6] with different processing techniques used to process the material (see section on second generation fuels). The largest potential for supply comes from countries with large agricultural areas and low cost of production (for example, from developing countries). Therefore, high unit production costs resulting from subsidised agricultural production on small land holdings in the EU are a major disadvantage especially in relation to biomass trade on the world market. However, the EU has proposed a number of scenarios to estimate the likely domestic biomass production ability for local energy supply. The first is to determine the area of land that is responsible for production of grain that is excess to domestic requirements and convert a percentage of this to biomass crop production. The second is to specify an area of the land that is currently classified as 'set aside land'[7] and change this land use to biomass crop production. Third is to convert some of the permanent grassland (currently 74 million ha) to energy crop production.

Within the EU, agricultural resources that can contribute to this include crop residues (straw of which 25% is estimated to be recoverable), agro-industrial residues (food processing of which 100% is estimated to be recoverable), animal wastes (manure 12 – 25% recoverable depending on production system) and energy crops.

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[6] Biofuels in the European Union – A vision for 2030 and beyond. Final draft report of the Biofuels Research Advisory council. (Pre Final Report 2006 – Directorate General for Sustainable Energy Systems)

[7] Under the Common Agricultural Policy (CAP), set aside land is land area that is subsidized to be left out of production. Under the 2003 CAP reform, energy crops are able to be grown on set aside land. However, the oilseed crop area is limited to approximately 1 million ha.

The other major biomass contributor is the forestry industry with about 70 – 75% of the global wood harvest available for renewable energy production (Biofuels Research Advisory Council). Energy crops are seen as a very likely source of future energy supply which will increase the total biomass production ability of the EU to supply a greater percentage of total energy requirement.

Biomass imports from developing countries and domestic urban organic waste are considered other likely possibilities to contribute to the renewable energy supply in the EU. However, this is not discussed here as it is not directly relevant to the opportunities for primary producers in the EU.

An important political and moral consideration concerning the importation of biomass from developing countries is the slash and burn of native forest to make way for palm plantations. This has been seen in the destruction of the Malaysian and Thai forests (and the lives of thousands of animals) with the increasing demand from developed economies for cheap palm oil for the biodiesel industry. These concerns have given rise to the implementation 'Environmental Compliance Standards' which should guarantee the source of palm oil (or other energy source) is not from an area developed by loosely regulated 'slash and burn' opportunists.

With common understanding of the environmental values that underpin this renewable fuel industry, the undeniable upside of increasing the wealth (access to foreign currency) will be available to those in areas capable of producing large amounts of biomass relatively cheaply.

For biomass production potential of developing countries, see www.fairbiotrade.org.

Economic benefits arising from the biofuel industry in the EU

Biofuels have proven to be a major economic opportunity for the European Economy by way of job creation and export of technologies. The biofuels research advisory council to the European Union Commission reported that for every 1% inclusion of biofuels in total fuel consumption, between 45000 and 75000 new jobs will be created[8].

Job creation in the renewable energy industry was evident during my tour. The EU has also reapt the rewards of development and export of efficient extraction technologies, one example of this is the generation of electricity by wind turbines.

The most efficient wind energy technology was recognised as originating from the EU[9] (Puget Sound Energy – Danish technology imported to America). Similarly, during my travels (2006), it was broadly recognized that German oil seed crushing equipment and plant excellent quality in terms of engineering and service expertise.

Expected fuel demand in the EU

It has been observed, in the past that energy demand increases in relation to an increase in GDP. However, with increasing efficiency and a more rational use of energy, the two measures are expected to diverge. In-spite of this, the members of the EU are expected to increase their demand for fuel with increased mobility in both personal (14%) and freight transport (74%) between 2000 and 2030 (Biofuels Research Advisory Council). It is not expected that this future demand for fuel that cannot fully be compensated for by renewables and will lead to an increase in demand for imported fossil fuel.

Within the transportation sector, liquid hydrocarbons (from both renewable and fossil sources) are expected to cover 97% of the market and liquid petroleum gas will provide another 0.7%. Gas fuels and alcohols are expected to increase but only on a relatively small scale and electricity will increase due to the electrification of the rail system. The two strongest increases in demand will be for diesel at 51% (road freight) and kerosene 60% (aviation) - both of these fuel types can be sourced from renewable feedstocks. The current EU policy framework is set around these estimates.

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[8] Biofuels in the EU report by the Biofuels research advisory council to the European Union Commission. Directorate General for Research Sustainable Energy Systems. 2006

[9] Puget Sound Energy - Hopkins Ridge Wind project. 83 wind turbines spanning 11 000 acres near Dayton, Washington. Each turbine produces V80 - 1.8MW. Project serves 50 000 customers annually.

European policy

Greenhouse gas emission reduction, the opportunity to diversify agricultural production and the creation of new jobs through a renewable fuel industry have paved the way for the EU Commission to create a favourable business environment to assist in the establishment of their biofuel industry. As noted above, the EU is aiming for one quarter of its transportation fuels to be supplied by biofuel provided by European Industry by 2030.

To facilitate this overriding aim, the EU has set in place policies to both foster development of the research industry and assist in the development of markets for the fuel product. In the 2003, the Biofuels Directive created a market by setting a mandate of 5.75% biofuel inclusion to all transportation fuel by the end of 2010. An Energy Taxation Directive was also formed concerned with the non-mandatory reduction of excise duty on biofuels. All excise concessions are valid for a maximum of six years[10]. After this time, member countries must find other inducements to encourage the industry. The Dutch government has already addressed the problem by reducing tax exemptions from 2006 and placing a mandatory obligation on the oil companies to include 2% renewable fuel in the transportation fuel sold in that country[7].

The European Commission policy guidelines are interpreted and implemented by individual member states to suit their circumstances. These taxation and biofuel inclusion directives have been included in member state legislation in very different ways. For example, in France which has the ability to produce oilseed feedstock, fuel production is untaxed up to a quota level. This tax concession is only applicable to oil produced in France. The French Government issues a tender for the quotas and prospective producers submit proposals for production. Currently, individuals can press oilseed for their own use and this is untaxed. Tenders for new volume will continue until 2015. I was informed France's rapeseed production capability means that it can be self sufficient to 5% blended diesel without competing with food-crop interests[11]. The EU as a whole will not be self-sufficient to this extent.

In comparison, Germany which also has good agricultural resources encourages oilseed crop production, processing to biodiesel and sales through taxation subsidies for all biodiesel sales. Wholesale pricing in February 2006 was; €90/m^{3}for 100% biodiesel, €150/m^3 for blended biodiesel and €470/m^3 for fossil diesel.

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[10] Biofuels in the EU – Changing up the gears. Rabobank 2005.
[11] In conversation – Jean-Louis Benassi of PROLEA (2006)

The lack of discrimination of country of origin for the biofuel means there is less protectionism for German agriculture and marketers are free to take advantage of any supply source. It also effectively subsidises foreign producers.

Labelling and guarantees assist with market acceptance. Up to 5% blend, no labelling is required (advocates are trying to change this to up to 10% volume). Currently in the EU, car engine performance is guaranteed up to 20% volume.

Until recently, the European Commission set the standard for biodiesel based on the properties of oilseed rape. This behaved as an effective trade barrier to the importation of alternative oils from cheaper producing nations. In the advent of the 5.75% mandate, fuel producing companies worked around this by blending other imported oils (that don't reach the standard on their own) to bring the final product standard up to the EU biodiesel blend standard (EN14214). The EU currently imports palmoline (separated oleic fraction of palm), canola oil, soybean oil and oleic sunflower oil. The Commission has more recently proposed the amendment of the standard EN14214 to facilitate the use of a wider range of oils that have no effect on the performance of a vehicle.

Export taxes in some countries limit their ability to sell oil to these EU markets for blending. For example, Argentina is taxed on plant oil but not biodiesel where as Brazil has no tax on vegetable oil or biodiesel. Similarly, import tariffs further complicate access to these markets, for example, France wants to promote the use of domestically produced feedstocks and places no tariff on seed and meal, but does place a 6.5% tariff on vegetable oil. At the time of travel Jean-Louis Benassi of Prolea advised that the biodiesel tariff had been recently reduced from 10% (under a miscellaneous classification) to 6.5% (now classified as esterified oil). This tariff rate is altered depending on the economic status of the exporting countries. Exports of the developed countries of the Cairns Group (eg Australia and America) are taxed at the full rate (6.5%). This reduces to 0% for developing countries (e.g. Africa and Caribbean), Eastern European countries (e.g. Ukraine) are subject to 2.9%. These tariffs are also under review, providing trade opportunities to developing countries that have more efficient means of producing biomass. Environmental compliance standards (described previously in "Future biofuel production in the EU….") will be in place for the importation of biofuel feedstocks or products. These changes were due to be discussed in the bilateral trade discussions (EU – Mercosur[12] October 2006).

[12] Mercosur is a common market between Argentina, Brazil and Uruguay

“Set aside” land[13] may be used to produce non-food/energy crops to a maximum of 1 million tonnes equivalent of soybean meal. This equates to and is capped at 1.5 million ha for EU Commission budgetary control. At the time of writing, this limit had not been reached. ‘Set aside’ land is subsidized at € 45/ha *additional* payment for an energy crop on the area. This subsidy is not available to new countries entering the EU system since they have modified agreements (i.e. they sacrifice this for other advantages).

The Situation In The USA

US policy

In 2004, Americans consumed 190,313,000t of oil in the form of gasoline or diesel[14] ! The main driving force for establishing a renewable fuels industry in America has been a desire to reduce dependence on imported oil (“75% reduction in oil imported from the Middle East by 2025” – George Bush). In response to this, the American Farm Bureau Federation, the National Farmers Union and commodity groups representing corn, soybean, sorghum, sunflower and canola lobbied during the development of the 2005 Energy Bill to successfully establish a Renewable Fuels Standard (‘RFS’). The RFS is a guaranteed minimum percentage of renewable fuel content in the transportation fuel in that state. The final RFS was set at 7.5 billion gallons of renewable fuel to be included in the national fuel mix by 2012. At the state level, farmers and environmentalists have rallied together to establish specific percentages to be included; for example, Washington state has a 2% RFS. Individual States have taken a more assertive approach to mandates with Montana and Hawaii at 10% and Minnesota at 20%.

Federal tax credits for biodiesel stand at US $0.01/ gallon per blended percentage point and is available to diesel marketers (i.e. 100% biodiesel attracts a tax credit of US $1 per gallon). The credit is theoretically passed on to the producer who can afford to sell the biodiesel to the marketer at US$1.00 / gallon higher than the retail price to the marketer who then redeems the credit from the government. The actual value that the biodiesel is sold for is determined by supply and demand in the marketplace.

[13] Set aside land is a classification given to agricultural land that is left out of production for environmental reasons. This attracts a subsidy for the land owner.
[14] International Energy Agency

The Federal clean air standards (2004 Energy Bill) continue to tighten for marketers of transportation fuel. New restrictions on automobile emissions of sulphur, carbon monoxide and introduction of smog mitigation programs drive the demand for biodiesel. The US Environmental Protection Authority (EPA) has mandated the use of ultra low sulphur levels in diesel. Sulphur levels have been reduced from 500ppm maximum permissible to at or below 15ppm.

The removal of sulphur from fossil diesel has reduced the lubricity of the fuel which must be replaced with another substance. The most cost effective candidate for this is biodiesel (at 2%). An inclusion of 2% biodiesel for all transport sector diesel fuels (i.e. a national mandate for B2) would create a market for 4.5 billion litres of biodiesel annually, (see section on biodiesel and the environment for more on environmental benefits).

In addition to Federal policy, individual States offer additional financial incentives. For example, low cost loans for ethanol plants, tax exemptions for ethanol plants and installation of fuelling equipment.

Other factors encouraging the production of biofuel in the US

The US demand for diesel fuels in the five year period between 1997 – 2002 was 60 billion gallons per year (228 billion litres per year) (source: U.S. Department of Energy). Over half of this was used by the ‘on highway’ transportation sector. While demand is projected to grow by nearly 60% over the next 20 years, domestic oil supplies are dropping and refining capabilities have remained stagnant (for more detail here, see the Energy Information Administration of the US Department of Energy, (DOE)).

Other motivating factors include, creation of new industry and distribution of wealth to rural areas. In 2005, farm subsidies provided 31% of net farm income[15]. These subsidies are under threat from the World Trade Organisation which deems them an unfair trade advantage. Energy payments are seen as an alternative to traditional commodity subsidies. More recently, environmental concerns with the threat of global warming (Americans consume 25% of global oil production) is creating demand for environmentally sustainable research and extension.

[15] The New Harvest – Biofuels and windpower for rural revitalization and national energy security. Patrick Mazza and Eric Heitz. November 2005.

The ability of biodiesel to fit into the renewable fuel industry as a fuel extender, oxygenate and lubricity replacement, as well as improving the margins for fuel marketers has affirmed its place as the fuel additive of choice in the USA.

Effect of US policies

Increased production and demand for biofuels

In 2005, the US produced 285 million litres of biodiesel. This is expected to grow to 1.9 billion litres by 2012. (National Biodiesel Board (NBB)).

The biodiesel industry in America was preceded by the ethanol industry. As such, the ethanol industry serves as a good model for the biodiesel industry in terms of response to policy creation, market development and capital investment. The creation of supportive policy in the ethanol industry has resulted in 15% of total US corn usage going to ethanol production (1.6 billion bushels = 40.64 million tonnes) in 2006. This is expected to increase to 26% of corn use (80 million tonnes) by 2010/2011. In 2005, the 4 billion gallons (15.2 billion litres) supplied only 3% of the total gasoline usage (532 billion litres). The forecasted expansion in ethanol production in the next ten years is to 35 billion litres. This expansion is expected to swamp the feed market with dry distillers grain (DDG)[16] displacing both corn and soybeans in feed rations. This market trend will have a major impact on soy oil market share with improved oil price but lower soymeal usage and crush margins [17].

[16] 1 bushel of corn (27.2kg) produces 10litres of ethanol and 8kg DDG – high protein feed)

[17] Remarks made by Bob Bothast of National Corn to Ethanol Research Center (in Edwardsville, Il) to a farmer luncheon (February 2006)

Domestic and foreign investment

The principle driving factor for capital investment biofuels in America has been the introduction of policy that creates guaranteed markets, that is, the Renewable Fuel Standard (RFS). The guarantee of a market gives investors security and the confidence attracts investors from all over the world. It was interesting to see that Australian investors have invested in ethanol plants in Washington State due to this legislation (2% RFS) rather than invest in Australia which does not give the same market encouragement. It is also important to note that ethanol has become a major industry in Washington which is a corn free state! Corn is freighted from the mid-west states that do not have a renewable fuel mandate and into the north-west purely due to market creation.

Pitfalls encountered by US policy makers

Policy setting for the renewable fuel industry has not always resulted in the intended outcome. One of the oversights in the creation of a renewable fuels market has been the inconsistent allocation of government funding to project development. Erratic funding over time creates a risky environment for private investment. This has been one of the major problems in attracting investment in research into cellulosic ethanol, to assist in the development that will reduce the overall cost of processing. Steady funding over the years in Denmark and Germany has enabled lower risk investment and encouraged the development of world class technology (for example, wind power generation) which they are now exporting to the world.

Policy also needs to focus on the outcome rather than the means. Since (in the US) biofuel is only spoken of in terms of ethanol and biodiesel, the US has forgone opportunities with butanol (made from the same feedstocks as ethanol) which is cheaper, requires less energy to make and can be transported in the same infrastructure as fossil fuels compared with ethanol and yet, not readily accepted.

A third lesson from the US Ethanol model is the direction of available funding for individual projects. Following the 2004 Farm Bill, grants were made available for capital infrastructure, however, no money was made available for feasibility studies. As a consequence, many plants were built that were poorly planned in terms of feed stock supply and suitability (e.g. one ethanol plant was built for processing artichokes which proved to be an unsuitable feedstock; causing the venture to fail).

Opportunities for the Australian agricultural industry as a result of US policies and production ability

- Increasing (but self regulating) commodity prices for wheat and canola as U.S. land use is diverted from this traditional production into energy production and products are targeted to energy markets.

Developing Countries: India as a Case Study

The ability to turn agricultural products into energy provides developing countries with two significant opportunities; one is increased food security and wealth in rural areas via provision of energy and employment, the second is the access to foreign currency via low cost production of biomass which is in demand in wealthy developed countries.

The Indian government is planning to make use of these opportunities through investment and development policy directed at arid climate plantations. The current per capita use of petroleum in India is extremely low at 0.1t/yr/capita compared with 4t/yr/capita in Germany and 1.5t/yr/capita in Malaysia ('Jatropha project' pdf supplied by Sreenivas Ghatty). Although India is home to 17% of the world's population, this low per capita usage gives rise to the aim of 20% biodiesel by the year 2011/2012. Supply will be mainly from large Jatropha plantations.

India currently imports 70% of its petroleum needs. Demand in 2006/07 was expected to be 120Mt with domestic production of crude oil and natural gas at around 34 million tonnes[18]. To redirect the money spent on oil imports to rural areas, the planning commission of the Government of India has set a target of 5% blend of biodiesel with fossil diesel by 2007. To achieve this target, the government needed to encourage the development of 2 million hectares of Jatropha plantation reaching maturity by 2007.

In remote communities, decentralised and localised energy production makes sense, given the volatile and relatively high energy prices, poor infrastructure and unreliable supply. Moreover, the system diminishes their reliance on the culture of political promises.

[18] Agrotechniques for biodiesel plantations in rain fed areas– Central Research for Dryland Agriculture 2006

Plantation systems such as pongamia or jatropha do not need the same level of continuous technical expertise that is required in some other decentralized systems such as wind or hydro. It allows community ownership of the trees and processing business, which gives control over production capacity and expansion according to their own requirements.

Overall, this system requires a relatively small capital investment and is considered a low-risk operation. This is ideally owned and operated by a local co-operative with the savings invested back into community.

The success of this decentralised energy production and the reliability it brings can be seen in an early business where community members collect the seeds from wild growing pongamia trees (originally utilised for shade). The oil was then extracted and used for stationary irrigation pumps. This gives water reliability and in turn, more reliable food production and income. This early system is now being further developed with incentives from the Indian government to assist in the rapid growth in demand for energy.

In 1995, an economic survey conducted by the Indian Government classified 100-150 million ha of land as degraded or wasteland. Wasteland is defined as land that under current conditions (political, climatic, management) is not capable of food production. The Government policy is to encourage the development of 25million ha of this land for production of Jatropha curcus and/or Pongamia sp. Plantations. Plantation investors would pay a nominal lease fee of 1 Rp/ha/yr. This cheap access to large areas of land has attracted large investors in anticipation of access to carbon credit trading. These plantations will provide significant employment in rural areas. It is expected that each hectare of plantation will give 364 working days. The crushing process will be decentralised to reduce freight (a major benefit where roads and vehicles are often in poor repair) and encourage local employment. Pure oil will be used in stationary pumps and generators while the remainder will be converted to biodiesel and blended with mineral diesel.

Note: Further investigation shows that there are a number of assumptions that have been made that are likely to greatly distort the estimations made for oil production per unit area (up to 5t /ha/year at 30% oil). All of the information freely available has been extrapolated from individual trees grown in isolation with no competition nor pest or disease risks associated with monoculture production. The first official trials were begun by Tree Oils India three years ago and harvest results are due to at the end of 2006.

Figure 1: Jatropha plantation for industrial oil – Andrah Pradesh

Interest in the plantation has given rise to employment in plant breeding and research which has international interest. Australia has imported Pongamia trees selected for domestic research.

Policy in Australia

In 2005, Australia's demand for petroleum based fuel was approximately 43 billion litres.

Table 1: Product demand by component of petroleum based transport fuels

(Source: Biofuels Taskforce).

Automotive gasoline:	47%, or 19,962 ML
Automotive diesel:	34% or 14,462 ML
Jet fuel:	10% or 4,329 ML
Liquefied petroleum gas (LPG) —automotive use:	6% or 2,547 ML
Others, including lubricants:	3% or 1,200 ML.

To become a world leader in the biofuel industry, Australia must develop long term policy that favours investment and co-operation amongst all players in the industry. Taxation and regulatory standards as well as performance criteria for transportation vehicles have been proven as successful industry stimulators in the EU and USA. The current climate of only token support leaves Australia well behind in sustainable energy provision and threatens all products that utilise Australia's 'clean, green' image as a marketing tool. So far, the Australian government has set a non-mandatory target of biofuel production and use in Australia of 350 ML (<1% total fuel usage) to be reached by 2010.

There are no penalties for not reaching this target. Until July 2011, domestically produced biofuel is tax exempt (imported biofuels are subject to full tax). This equates to a subsidy of 38.143 c/l. After July 1 2011, the 38.143 c/l subsidy is scheduled to be gradually reduced according to the table below:

Table 2: Effective fuel tax rebates for Alternative Fuels at 1 July 2003 to 2015 (cents/L).

Source: Biofuels Taskforce

	Ethanol			Biodiesel		
Year	Fuel tax	Production grant	Effective tax	Fuel tax	Production grant	Effective tax
2003	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2004	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2005	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2006	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2007	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2008	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2009	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2010	38.143	38.143	**0.0**	38.143	38.143	**0.0**
2011	38.143	35.643	**2.5**	38.143	34.343	**3.8**
2012	38.143	33.143	**5.0**	38.143	30.543	**7.6**
2013	38.143	30.643	**7.5**	38.143	26.743	**11.4**
2014	38.143	28.143	**10.0**	38.143	22.843	**15.3**
2015	38.143	25.643	**12.5**	38.143	19.043	**19.1**

Note: The Australian Government has determined the final net effective fuel tax rates for alternative fuels but the mechanism for delivering these net effective fuel tax rates has not yet been decided. One option is to use a combination of a fuel tax rate and a decreasing production grant which is shown in this table. Another option would be to directly legislate the effective fuel tax rate for the product.

Source: Treasury

The adoption of biofuels in Australia is most likely to begin as a fuel additive as is exemplified by the US situation where tightening pollution controls restrict the use of traditional fuel additives. In the example of increasing restrictions on the permissible sulphur content in fuel, the cheapest replacement to restore lubricity to the fuel is biodiesel. As is evidenced by the proactive countries that have encouraged the development of biofuel industries in their economies, long term support is essential to achieve competitiveness with the long established and rationalised petroleum industry.

Having said this, petroleum industry subsidies are often overlooked when considering the economic cost of establishing a biofuel industry in Australia.

For more information on the Australian government's perspective on the Australian biofuels industry, visit the report of the Biofuels Taskforce to the Australian Government, August 2005 (pdf available on web).

Investment climate

On the surface, on farm biodiesel production would seem an ideal opportunity for farm diversification and in some situations, it is. Setup costs are relatively low, feedstock supply is local and markets are close. Unfortunately, in many cases, small scale production has encountered problems gaining equivalent or greater value from the final product when compared with selling the grain on the open market.

The investment strategy of many of the larger companies reflects attitudes which have benefited from lessons learned from similar emerging industries. Companies that are ideally situated to take advantage of the biodiesel industry, for example, Archer Daniel Midlands (ADM) in America and Gardner Smith in Australia have not jumped in amongst the frenzy of speculative investment associated with an emerging industry.

The speculative investment frenzy in Australia is demonstrated by the movement in stock values of Australian Biodiesel companies The Australian Financial Review (Oct 14-15, 2006) reports that 3 out of five of Australia's major biodiesel companies had significantly dropped in value in the year since listing. The biggest losses suffered by Australian Biodiesel Group at -66.8% followed by Australian Renewable Fuels at -40.9%. One of the main reasons sighted for this fall in investor interest was "….uncertain legislative environment on the treatment of rebates under the Fuel Tax Act". This, in combination with other factors, has transformed the forecast profits of one year ago into losses of the equivalent value.

The ethanol industry (policy and investment response) in the U.S. serves as a likely model for a newly emerging biodiesel industry. It was the policy of the larger, well placed companies to sit and wait for all the rushed investments to fail and then buy them for a fraction of their set up cost and manage them efficiently, taking maximum advantage of the strong position they already hold in the market chain.

Summary of factors that encourage investment

From my observations of successful biofuel businesses, particularly in the US, the following factors encourage investment:

- Secure markets such as those made by mandates / renewable standard fuel blends and environmental emission standards
- Specific / niche market with limited alternative supply (such as remote or environmentally sensitive areas)
- Longterm and transparent policy and funding
- Competitive advantage: control of feedstock supply, long term contracts, proximity to market (note: long term contracts from feedstock suppliers may be hard to secure in a bullish market)
- Proven management team (buy in the skills lacking)
- Control the chain from production to sales and distribution.

Level the Playing Field – Subsidy in the Australian Petroleum Industry

Australia's current dependency on oil is a direct result of ongoing subsidies to the petroleum industry. These public subsidies to the extraction and use of petroleum products are a substantial barrier to the development of a renewable energy industry. One of the most persistent arguments that the Australian (and American) governments use for failing to push for a reduction in emissions (eg ratify the Kyoto protocol) is the perceived detriment to the economy. De Moore (2001) estimated that the global subsidy for energy use (80% of which is fossil based) is US$240 billion. Further, Anderson and McKibbin (1997) showed by modelling the global economy that reductions in these subsidies would lead to improved economic efficiencies with significant reductions in greenhouse gas emissions. Finally, the release of the Stern report (October 2005) leaves no doubt that the cost of reducing dependence on fossil energy is a very small and short term cost in comparison with not acting to abate greenhouse gas emissions on a global scale.

The table on the following page is taken (with permission) directly from the discussion paper written in 2001 entitled "*Public subsidies and incentives to the fossil fuel production and consumption in Australia*" by Chris Riedy (Institute for sustainable futures, University of Technology (Sydney).

Table 3: Summary of annual ongoing financial subsidies and incentives to fossil fuel production and consumption in Australia.

Source: Riedy, C 2005, 'The Eye of the Storm: An Integral Perspective on Sustainable Development and Climate Change Response', PhD thesis, University of Technology, Sydney.

Subsidy or Incentive	*Annual Value ($ million)*	*Comments*
Greenhouse Gas Abatement Program (GGAP)	81.8	GGAP is a competitive funding mechanism that provides $400 million over 4 years for greenhouse gas abatement. The subsidy estimate comprises Round 1 funding to projects that support coal, natural gas or petroleum use.
Tax benefits for salary packaging motor vehicles	750	Subsidy could be as high as $1.2 billion depending on the assumptions made.
Reduced import duty for 4WDs	513	
Automotive industry support	400	
Non-recovery of agency costs	258	
• AGSO	34	Alternative estimates using differing assumptions arrive at a similar figure.
• DISR	28	
• State departments	196	
Inappropriate company tax concessions	186	Actual subsidy is probably higher due to implementation of new tax concessions since the estimate was made and lack of data for many of the concessions.
R&D support for fossil fuels	153	
Diesel Fuel Rebate Scheme	-	The scheme is worth $1.98 billion per year but does not meet the definition of a subsidy.
Diesel and Alternative Fuels Grants Scheme	665	
Fuel Sales Grants Scheme	210	
Fuel excise reduction	635	Lost tax revenue in 2001-02.
Road and car parking subsidies	2,000	This is likely to under-estimate the real subsidy.
Electricity supply subsidies to aluminium industry	410	This does not include one-off subsidies of between $577 million and $953 million provided to the aluminium industry.
State energy supply subsidies	228	
Direct subsidies to Stuart Oil Shale Project	Up to 36	This does not include one-off subsidies of about $18 million.
Timor Sea Arrangement	8	
Transmission pricing arrangements	Not assessed	
TOTAL	$6.54 billion	
Note: The table does not include one-off payments to specific fossil fuel development projects, although a number of these subsidies have been discussed in the text.		

According to the paper from Riedy (sourced above), in the first round of funding for the Greenhouse Gas Abatement Programme (GGAP), $93 million was allocated, of which, $81.8 million was allocated to projects which at least partially support the fossil fuel industry. Although these projects aim to improve efficiencies of the fossil fuel industry, ultimately, they are still net greenhouse gas emitters. Such a large portion of the funding further entrenches our dependence on polluting energy sources.

In 2005, the Australian subsidy for the use of fossil fuel in the transportation sector had risen to: AUD$6.937 billion compared with AUD$104 million for the renewable transportation fuel industry[19].

There are many ways the government could find extra funding for the development of renewable and sustainable fuel sources. The most commonly discussed include increasing taxes on high pollution contributors such as taxing 4WDs at a higher rate than more fuel efficient cars. Another and more direct option, in the establishment of the renewable fuel industry and reduction of carbon dioxide emissions, would be to transfer some of the petroleum industry subsidy to sustainable fuel research, development and capital infrastructure.

If the ‘playing field’ were to be more even, that is, subsidies were more balanced, the renewable fuel industry would attract the confident investment it needed to invigorate a self sufficient, sustainable industry both economically and environmentally.

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[19] Riedy, C 2005, 'The Eye of the Storm: An Integral Perspective on Sustainable Development and Climate Change Response', PhD thesis, University of Technology, Sydney, http://adt.lib.uts.edu.au/public/adt-NTSM20050603.101829/index.html.

Process

There are two main routes for the production of transport fuel from carbon containing fossil energy (primary energy). The first is via synthetic crude and conventional refinery to gasoline and diesel and the second is gasification of coal to synthesis gas (syngas) and Fischer-Tropsch technology to diesel fuel.

The production of biofuel from biomass follows the same two routes depending on the type of feedstock. In addition, biodiesel can be made directly from the oil contained in some plants. Energy feedstocks that do not contain carbon are only useful for the production of hydrogen. Hydrogen can be used directly in combustion engines or as an intermediate for the production of other liquid fuels. Currently, one of the reasons that hydrogen is less attractive than other fuels for transportation is due to the extensive infrastructure that already exists for liquid fuels (the other reason is prohibitive costs). There is a natural advantage to fuels that can be incorporated into existing infrastructure and combustion engines.

Evolution of biofuels and processes

Most new factory designs incorporate the potential for expansion with emerging technology and feedstock. It is widely accepted, for example, that the design of an ethanol plant needs to have the ability to integrate lignocellulosic feedstock capacity. Current biodiesel and ethanol plants will need to integrate both biochemical and thermochemical transformation stages. The value of 'waste heat' is now being harnessed for the biochemical phase and capture and reuse of gaseous by-products can also be integrated into the design (e.g. the capture of hydrogen for generation of electricity).

The Australian biofuel industry has been established on tallow and waste cooking oil. Although these cheap feedstocks are economic to use for biodiesel they are limited in supply and the quality of biodiesel produced is not acceptable on the world market. This has given rise to the increase in demand for biodiesel produced from canola oil to act as a blending agent to improve the cold climate performance of the biodiesel sourced from more saturated fats. Unfortunately, the use of oilseed crops as the main source of renewable diesel and current processing techniques are suitable only for the interim period between the establishment of the industry and the introduction of technology that is more efficient in terms of energy, carbon, land use and cost. A number of avenues for progress are currently being developed at a pilot stage. Some observed during my travels are discussed below.

Catalytic advancements

Under the leadership of Dr M. Hara, The Tokyo Institute of Technology has developed an effective solid catalyst that is cheap and easily recoverable, drastically reducing the costs and energy requirement for the conversion of vegetable oil to high grade diesel and glycerol. It directly replaces the soluble alkaline catalyst used in the conversion of vegetable oil/animal fat to biodiesel (commonly sodium or potassium hydroxide). The new solid acid catalyst is formed by the sulphonation of incompletely carbonized organic material such as glucose or cellulose (process described below). This is chemically stable and has a relatively high number of active sites compared with other solid acid catalysts (and over half the activity of the liquid sulphuric acid catalyst). The catalyst can be reused many times with tests showing no loss of activity even with heating to 180ºC.

The carbonised acid is simple to make, with cheap starting materials. The process begins with the carbonisation of medical grade cellulose (5 hours) or glucose (15 hours) at 450ºC with atmospheric nitrogen being passed through at 100 l/sec. Sulphonation then is the result of the carbonised cellulose / glucose being mixed in sulphuric acid at 150ºC for 10 – 15 hours. The process is completed by washing for 2 -3 days in ionized water. A relatively large volume of catalyst is needed for the conversion due to the comparative surface area of inorganic solid catalyst (50m^2 per gram catalyst) with the carbonized acid catalyst which has only 1m^2 of surface area per gram catalyst. However, the volume required is not a drawback since the cost catalyst is approximately $0.01 per gram, it is safe to handle, reusable and non-toxic.

The advantage of acid catalysts over the more commonly used alkali catalyst is that they are not sensitive to free fatty acids in the fats and oil which means that there is no expensive pre-treatment of the oils before processing (deacidification and pre-esterification). The drawback of acid catalysts is that efficiency is reduced by water in the reaction mixture[20].

[20] Biodiesel, the comprehensive handbook. Martin Mittelbach and Claudia Remschmidt. 2005

Figure2 (left): Sugar (D-glucose) converts to Carbon based solid acid catalyst via carbonization and sulphonation. Yield 85%

Figure 3 (Right): Biodiesel top layer, glycerol lower layer, catalyst middle. Chemical resources lab, Tokyo Institute of Technology

The biggest drawback of the solid acid catalyst is the reduced number of active sites in comparison with the liquid catalyst, resulting in slower reaction time. While the chemistry of this is being addressed at the Tokyo institute of Technology, an American researcher has tackled the problem from a design perspective.

Oregon State University chemical engineer, Goran Jovanovic has developed 'micro-reactors' in which channels only the diameter of a hair are coated with solid catalyst. Alcohol and oil are forced through the channels. The resultant surface area exposure reduces the reaction time from 12 – 24 hours down to almost instantaneous. The micro-channel design also greatly reduces the area needed for the processing plant. It is proposed that a 3.8 million litre per year plant would occupy the space of an average desktop computer. The small size of the reactor means that they could be incorporated into an average farming operation or nearby co-op for local use, eliminating the need to freight raw feedstocks over long distances. Note: in July 2006, the micro-reactors were not yet licensed or commercialised.

Miles per acre and second generation fuel

Competition for food production and the concern about the land area needed to supply any significant fuel requirements has given rise to one of the most important concepts emerging from my study: "miles per acre". The global biodiesel industry has been established using high input crops such as canola, rapeseed and mustards. This has been an effective beginning where the biofuel market is a niche market and taxation policy and land use subsidies are favourable. However, there are two factors that render this strategy unsustainable in the longer term, as follows:

- Yield of oil per acre per year is insufficient to produce enough fuel to satisfy a significant proportion of diesel demand in any country.
- Relatively high economic and carbon costs are required during the growing season to produce low annual oil yields. Costs include machinery fuel use, wear and tear, fertilizer use (nitrous oxides released from agricultural fertilizer are a significant contributor to greenhouse gases) and, in some cases irrigation water are to be considered in the lifecycle analysis of biodiesel production.

These factors cast doubt on the overall carbon benefits of the diesel system and increase cost of the end product, thus limiting the cost competitiveness of biodiesel. For more information of life cycle analysis, see "Carbon and energy balances for a range of biofuels" – M.E. Elsayed. See also, "Biodiesel – the comprehensive handbook" Martin Mittelbach and Claudia Remschmidt.

If biodiesel is to become anything more than an insignificant novelty in the transportation fuel industry, the fuel production per unit area must be drastically increased and the cost of fuel feedstock must be reduced. These requirements have encouraged development in the areas of 'second generation biofuels' - the use of waste and/or biomass products for biofuel feedstock (e.g. residue after the primary crop has been removed or animal, plant or municipal waste) and the growth of 'biomass' crops such as willow with the aim of producing large volumes of exploitable energy per unit area of crop.

It is likely to be some time before second generation biofuels and biomass come on line and replace low yield/high input oil crops such as canola. Second generation fuels are seen as the future of biofuels, however, the high capital cost and specialized process restricts most people from investing in this technology and will continue to do so until costs come down and technology is widely available. In the interim, investment is being channelled into improving existing oilseed crops to expand the range of suitable climates for growth (eg oilseed mustards into marginal cropping areas) and into research into the development of alternative crops or the modification of existing crops to produce oil specifically for industrial purposes. This is discussed in more detail below.

Modification of existing crops

One of the biggest problems with biodiesel is its lack of uniformity. One variation that affects the biodiesel product is the different composition of mono, poly and saturated fats in the feedstock oil. In the US, breeding programs for mono-unsaturated oil at 94% and less than 2% saturated fat is seen as the ultimate starting feedstock oil for biodiesel. Similarly, in Germany, genetic modification focuses on the fatty acid profile as this is easier to manipulate than oil yield. Saturated fat content is directly proportional to the cetane number[21] and oxidative stability of the final fuel and inversely proportional to the gel point (cold weather performance) of the final biodiesel. For example, soy oil at 15% saturated fat has a gel point of approximately –0.5 ºC, canola at 6% saturated fats has a gel point of - 10º C and rapeseed at 4% saturated fat has a gel point of -15ºC (this is similar to mustards). Correspondingly, oxidative stability increases in order of rapeseed, canola then soy.

It was interesting to note that most of the breeding programs used traditional breeding methods in preference to modern genetic techniques. All breeders cited threat of restricting access to overseas markets as the main reason. However, during my travels, I was interested to learn that Germany imports genetically modified lines of canola seed for its superior oil characteristics. The company exports the meal so that it doesn't enter the food chain, but it should be noted that no part of any imported oil seed can enter the food chain in the EU (Rabobank 2006). Similarly, in Japan I was able to visit an importing warehouse that stocked genetically modified soy meal from the US (with the endpoint use for human consumption).

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[21] Cetane number is a measure of a fuel's ignition delay (period between start of injection and ignition). Higher cetane fuels have a shorter delay than lower cetane fuels

Figure 4: Canola breeding – University of Iowa 2006

In America, seed corn companies are breeding varieties that will be more efficient at converting corn to ethanol. The use of these varieties is expected to add US$ 1- 2 million / year in revenue to a 150 million litre/year plant.[22]

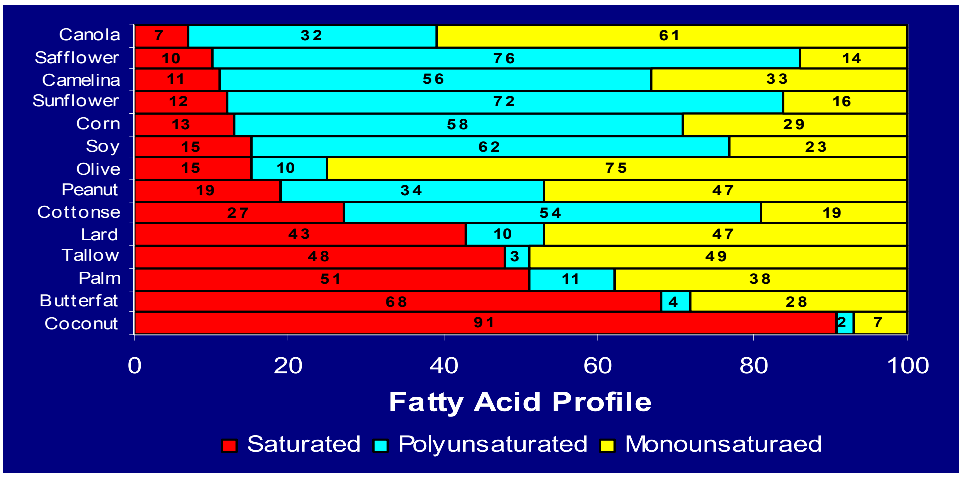
At the John Innes Centre for plant breeding (Norwich UK), the focus is to work on plant characteristics that improve the growth and agronomics rather than look at the oil production in isolation. These characteristics include canopy structure, light interception pod shatter and disease resistance. Oil is not the primary focus of the work mainly due the observation that a 15% oil increase is equivalent to a 2 % yield increase. Funding constraints also dictate that improvements should remain beneficial to the whole industry rather than designed to benefit one sector (such as industrial oil).

Some biodiesel producing companies are investing in the development and production of proprietary lines of seed with qualities that favour industrial oil qualities. They are developing industrial use plants with the longer term intention of isolating themselves from competition from food industry pricing (i.e. canola for human consumption). For example, there is some interest in Australia in expanding the cropping area into drier regions with mustards for biodiesel use. Similarly, in America, BlueSun Biodiesel® is investigating of camelina for regions with an annual rainfall of 250mm – 400mm (with yield aims of 2t / ha).

Camelina has a lower oil yield than mustards (mustard is 35% oil), but the meal does not contain glucosynolates. Like canola and mustard, camelina is a nitrogen miner and requires fertilizer input which detracts from the overall environmental benefit. On the upside, the oil profile is highly suitable for biodiesel production with a high proportion of poly and monounsaturated fats.

Figure 5: Oil profile comparison of a range of plants suitable for biodiesel production

Source: BlueSun Biodiesel LLC. Reproduced with permission



New Crops – Algae

Algae is attractive from a biodiesel production point of view due to the low input costs and very high oil production per unit area of land. Algae is the original source of all fossil oil. In its living state, it is a natural sink for carbon dioxide, about one hundred times or more effective than a forest of the same area[23]. The other major advantage of algae over terrestrial plants is that there are an abundance of marine species, which negates the need for fresh water for its growth.

The growing of algae for industrial purposes has potential in Australia, due to Australia's abundance of sunlight (the main limiting factor in other countries interested in this technology) and our vast areas of flat land unsuitable for food production. In controlled (laboratory) conditions equivalent yields of 140 847 litres of oil per hectare have been achieved compared with 563 litres from soy[24].

The process of farming algae from flue gas (developed by Huntley – Redalji, University of Hawaii, Manoa campus)[25] begins with stripping oxygen from the gas (oxygen is toxic to the algae), to produce gas with a minimum 5 – 13% CO_2 (atmospheric is about 0.03%). The carbon dioxide and nitrous oxide gas is then pumped through algal chambers.

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[22] Bob Bothast. Feb 2006.
[23] Michael Borowitzka. Associate professor of Marine Phycology – Murdoch University, Perth on The Science Show 16/2/02
[24] Institute of Science in Society, press release 3/3/06 Green Algae for Carbon Capture and Biodiesel
[25] CO_2 Mitigation and Renewable oil from Photosynthetic Microbes: A new appraisal. M. Huntley and D. Redaljie. 2006.

These chambers are emptied each day into 'grow out' ponds where the conditions are set to encourage the production of saturated fats (30- 35ºC and deprived of nutrients). Production rates of $50g/m^2/day$ are expected, requiring 220t CO_2. This would produce about 60t /ha/yr of biodiesel . The water needs to be changed or sterilized daily to prevent build up of pathogens. The algae are then dried (again, Australia has ideal drying conditions) and the oil can be extracted. The algae is typically 35 – 40% oil (some species are 50%).

The remaining biomass product comprises 50% protein and 50% carbohydrate. The carbohydrate portion of the biomass has value in ethanol production.

There are three main options for use of the protein product, being use as animal (or human) feed, fertilizer or electricity production:

- Animal feed is the most attractive option economically due to the protein content. However, if algae were grown on a large scale, the feed available could swamp the existing stock-feed market. Another consideration here is the need to freshwater rinse the extracted protein to remove the salt.
- Fertiliser is another attractive option since nitrogen exists in amino acid form which is effectively a 'slow release' fertilizer (however, the salt would need to be removed here too).
- The third option, electricity production, is attractive due to the use of the product on site (avoiding transportation costs from isolated locations). However, to fully utilize the product for electricity production, further capital inputs are required. Further, selling power back into the 'grid' is very difficult in Australia (though becoming easier and much more common) in comparison with many other developed countries where the government encourages non-localised electricity production.

Due to some practical short comings[26] and high initial capital cost, the only commercially successful algae farms have been associated with capture of flue gases from power plants. It is a very intensive system due to the short life span of the algae and the re-release of carbon dioxide when they break down.

[26] Experimentation with open air ponds alone has not been successful due to the ease of contamination. In the 50yrs of attempting to manage the system, there have only been three species that have been successfully cultivated in an open air situation. Theses species were successful due to the toxic environment they lived in e.g. extremely high pH or very high salt content (10 x that of sea water).

However, 40% of the CO_2 and 86% of the nitrous oxide was utilized by the algae in ideal conditions. In addition, being directly attached to a carbon dioxide emission source, these projects are entitled to be part of the current carbon trading scheme.

The value of carbon credits available to projects such as this one is currently about US$8/t on the European market. However, it is not inconceivable that the value of this would rise as far as US$20/t as European restrictions tighten on the carbon CO_2 emitting companies (see section on carbon credits for more information).

Second generation fuel

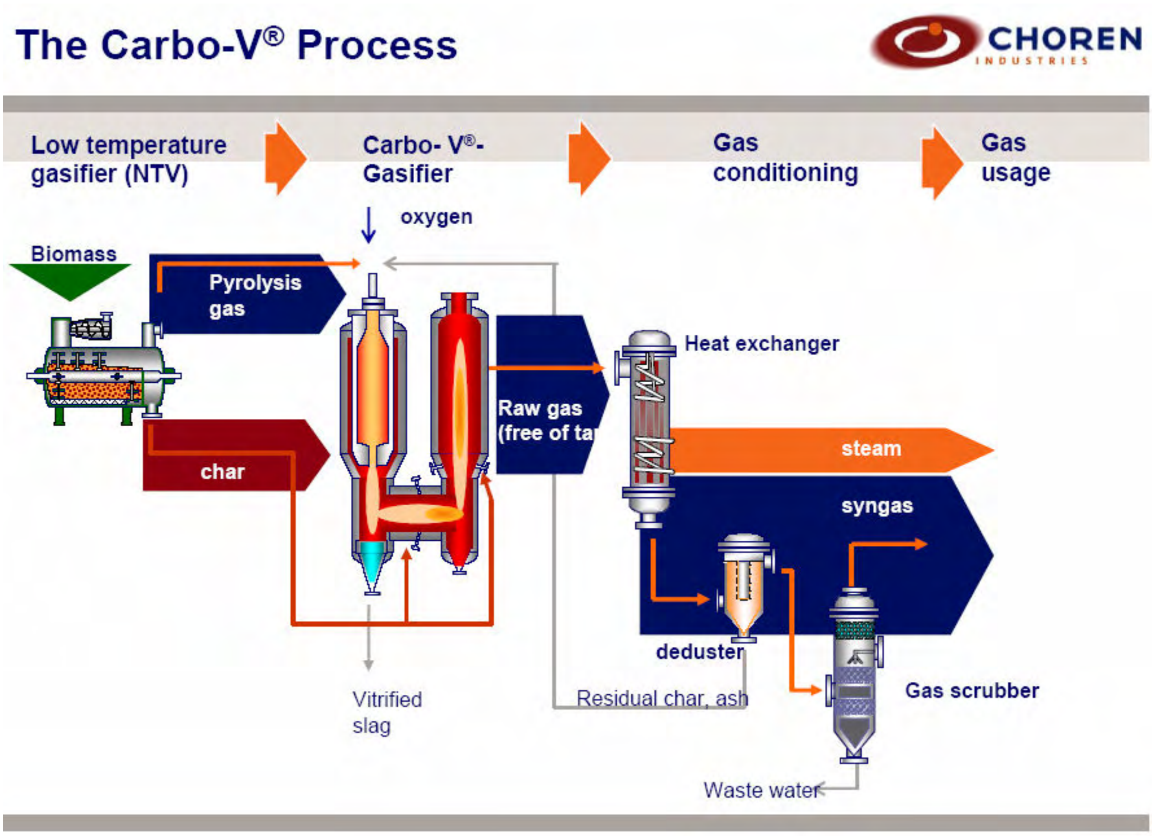
Second generation fuel directly addresses the issue of reducing land use competition between food and fuel production. It is the conversion of biomass into fuel via chemical or enzymatic processes. In terms of ethanol production, this is achieved via enzymatic breakdown of cellulose into simple sugars which are then fermented (as with conventional ethanol). Second Generation diesel (synthetic diesel) production is achieved via thermochemical routes (discussed below). Raw material (feedstocks) for both ethanol and synthetic diesel can be provided in many forms; eg municipal and agricultural waste, trees, grasses (Americans are successfully trialling switchgrass which is a high yielding biomass crop (15 – 20 t/ha/yr) and other biological material.

Second generation biofuels are more efficient than the conventional biofuels in terms of carbon saving and energy balances (energy in : energy out). However, the current cost of production and high costs associated with the capital setup, renders them commercially unviable. Due to the potential increases in efficiency and availability of cheap feedstock, there is much research into improving the economics of these systems. In 2005, the cost (2002 dollar value) of producing ethanol via cellulosic processes was US$2.25 per gal (3.8 l). This is expected to drop to US$1.07 per al by 2012 (which is the threshold value for significant market penetration) and to US$0.59 by 2020. The main cost savings will be achieved through reduced enzyme costs and increased conversion yields (2005: 65 gal/t biomass, 2012: 75 gal/t and 2020: 94 gal/t). There is also expected to be a decrease in the price of the biomass feedstock from US$53 /t in 2005 to US$30 /t in 2020 however, this is the least significant factor in the overall reduction in cost of production[27].

[27] National Renewable Energy Laboratory - Colorado

Similarly, advances have been made in second generation biodiesel. The biomass to liquid technology (thermochemical) involves the breakdown of biomass into a gaseous mix of carbon monoxide and hydrogen (known as synthesis gas/syngas) (Figure 6). Syngas is reassembled into diesel fuel via the Fischer-Tropsch process. The Fischer-Tropsch process is not new it was developed by Nazi Germany to produce synthetic fuel from coal.

Figure6: The Carbo-V process developed by Choren Industries (Germany). Biomass is converted to gas which can then be converted to diesel via the Fischer-Tropsch process



The syngas is then manufactured into liquid fuel via the following Fischer-Tropsch sequence:

- Adsorption of the carbon monoxide and hydrogen on a cobolt catalyst surface
- Chain growth begins when the carbon monoxide is broken down allowing the coupling of carbon and hydrogen and the separation of oxygen
- Chain growth continues with the addition of more carbon monoxide and hydrogen (long chain paraffin liquids and waxes are formed)
- Chain growth termination (influenced by temperature and pressure) and desorption of the molecule from the catalyst surface.

- The hot product is then cooled resulting in the separation of constituent hydrocarbons and synthesis water
- The final Fischer-Tropsch product is distilled and hydrotreated to yield high cetane synthetic diesel (SunDiesel® in Germany)

Converting biomass to synthetic diesel (in this case, SunDiesel) is more expensive than manufacturing standard biodiesel. Currently, the cost of production of SunDiesel is about €0.70 per litre (AUD$1.16). Although the price per litre is higher than standard biodiesel, the tax incentives in Europe leave plenty of room for profit. Another value that is important to consider is the energy efficiency of the different diesel production processes. Independent studies have shown that for each joule consumed in growing or pumping feedstock and fuel production, gasification technology gives a carbon dioxide saving of 85 – 90% compared with fossil diesel. Standard biodiesel offers a 50% carbon dioxide saving in comparison with fossil diesel.

Economy of Scale

A significant factor in cost competitiveness is economy of scale. Large plants are advantaged by their ability to allocate flat fixed overhead costs over more litres of output as the size of the plant increases.

The European Department of Energy found that low input, low output production is not profitable due to lack of supply of low cost feedstock[28] and the variable quality and quantity of oil produced. These factors result in high unit costs per litre of output.

Another observation was that small scale operations are generally dependant on cold press for oil extraction (unless they purchase the oil directly from a larger seed processing company). In systems that utilise cold press techniques, the meal left after press extraction can contain up to 10% oil. This carries two disadvantages the first is that meal sold for animal feed is generally priced according to protein content. The presence of oil lowers the protein percentage per unit weight. Secondly, the opportunity to process the oil remaining in the cake to biodiesel (and the resulting value) is lost.

[28] in direct competition with food markets without the scale to secure long term contracts or invest in plant breeding for industrial oil

Large scale operations carry the ability to produce byproducts with a market value. Small scale plants often lack the ability to further refine co-products such as glycerine or produce it in any commercial quantities. As a consequence, smaller operations can have to pay for the removal and disposal of glycerine (which, when unrefined is classed as a hazardous product due to the methanol content). Conversely, larger scale operations have the ability to produce large quantities of high value glycerine with a number of end uses.

It is also these companies that have the ability to fund research into deriving high value products from the current low value commodity such as feed.

This was demonstrated during my visit to Pacific North-West National Laboratories in Washington (PNNL). PNNL were working on a number of proprietary projects[29] for companies looking to increase cash-flow from their biofuel processing plants. Research being conducted included research into extraction of C5 sugars, sterols and copherols remaining in the oilseed meal after the wet milling process for ethanol. These products are worth US$20/lb if extracted, but currently are just fed to stock along with the remainder of the meal. The potential also exists for use on site for power generation. These projects are discussed in more detail below.

The acceptance of biofuels in the broader community is vital for industry success. This will be dependant on 'trouble free' use of the product. For this reason, production of a consistent product meeting or outperforming biofuel standards in every measure is essential to achieve in a factory dedicated to this purpose. The onus needs to be on the fuel producer to ensure a quality product. An example of this is the company BlueSun Biodiesel® which has captured a niche market through placing a warranty on their fuel in combination with emphasis on customer service provided with a product subject to stringent testing.

Under utilised Opportunities

One of the real opportunities that has become apparent through this scholarship has been the extraction of high value products from farm produced biomass. Improved conversion technologies have markedly increased the ability to extract and manipulate compounds that result in products that are at least as good (and in some cases superior) to their fossil counterpart. Further advances in biotechnology, (plant genetics and fermentation organisms) stands to improve the processes and products even further. Some examples of products that can now be made from biomass include plastics, paints, anti freeze, neoprene and golfing equipment.

[29] projects funded by larger companies who will own the resulting technology

Production of HMF

Improved conversion technology making use of farm produced biomass is the conversion of fructose to the base product hydroxylmethylfurfural ("HMF") via a two stage process known as "aqueous phase reform". This process was developed by James Dumesic of the University of Madison. HMF is a furan derivative that is used in the production of plastics and fine chemicals. It can be bought for US$98 per 5g from petroleum base. When converting from fructose, there is a 90% conversion rate and the cost of production is equivalent to $20- $30 barrel equivalent (conversation – Ryan West (University of Madison) - exact feasibility is now being studied by that research team). HMF can also be used for the synthesis of liquid alkanes to be used as diesel fuel.

Production of glycerol derivatives

In its natural state, pure glycerol (pharmaceutical grade) has many uses. It is consumed in products for personal / oral care, drugs, food, beverages and polyether polyols (for polyurethane). When produced as a by-product of biodiesel, it needs further purification (extra cost) to be considered for these uses. With the increase in production of biodiesel, glycerol has swamped the market dropping the value. In 2002, the value of crude glycerol was 30–40 c/lb. At US$0.05 /lb for crude glycerol, markets for stock feed and steam reforming to hydrogen become more attractive which are both very large markets and should prevent the price dropping any further[30]. In 2005, the price was approximately 20c/lb[31]. At this price, glycerol became attractive to chemists for use as a starting chemical with many possible derivatives.

Aqueous phase reform, in a one step process, is being employed to add value to glycerol. An American company, Virent Energy Systems is using liquid glycerol from biodiesel processors as the starting block for the production of super natural gas or hydrogen. These gases can be burnt in internal combustion engines to produce electricity or be further reformed to produce liquid fuel. This is a cost effective system for hydrogen production since it occurs at relatively low temperature and pressure and there is no need to volatilise water. Glycerol and water are reformed to super natural gas over a catalyst at temperatures between 200 ºC and 250ºC at pressures of 16 and 40 bar respectively (heat is required and can be supplied by burning some of the hydrogen product).

[30] NREL report. Biomass Oil Analysis: research needs and recommendations. K Tyson et al. 2004

[31] Greg Keenan. Virent Energy Systems

The natural gas product, known as 'super natural gas' is composed of 30% hydrogen, 10% methane, 10% ethane, 10% propane and 40% CO_2. It has a heating value of 600BTU/ft^3. A 10kWe reactor consumes 2.2 gal/hr glycerol and has a 90% conversion efficiency giving a gas flow rate of 90l/min. Hydrogen and carbon dioxide can both be easily purified from this mix. The carbon dioxide has value as a pure chemical form or it could be sequestered making the whole process carbon negative (and potentially eligible for carbon credits).

In terms of cost, the process is most sensitive to the conversion efficiency of the process. At \$3.50per kg hydrogen produced, this aqueous phase process is competitive in the production of hydrogen compared with other small scale method. This is comparable steam reform using natural gas 56% efficiency and far better than the electrolysis of water at \$6.50 per kg hydrogen. It can not compete with the large scale production that produces hydrogen for \$1 – \$2 /kg.

At Pacific Northwest National Laboratories (PNNL), C_3 (tricarbon) type chemicals are being derived from glycerol. Products successfully derived from oils include[32]:

- In conjunction with Dow, they have derived polyol (foam applications) from fatty acid methyl ester (biodiesel) through hydroformulation and reduction;
- Polyols also have potential use in the form of resins in insulation;
- Achroylene used in polymers and is the precursor to acrylic acid used in absorbent diapers and coatings;
- Epichlorohydrin for almost all coatings;
- Propylene glycol (related to ethylene glycol) for use as antifreeze;
- Glyceric acid for the use in polyester fibres.

Although these are now technically possible, commercial viability is not known.

More from agricultural products

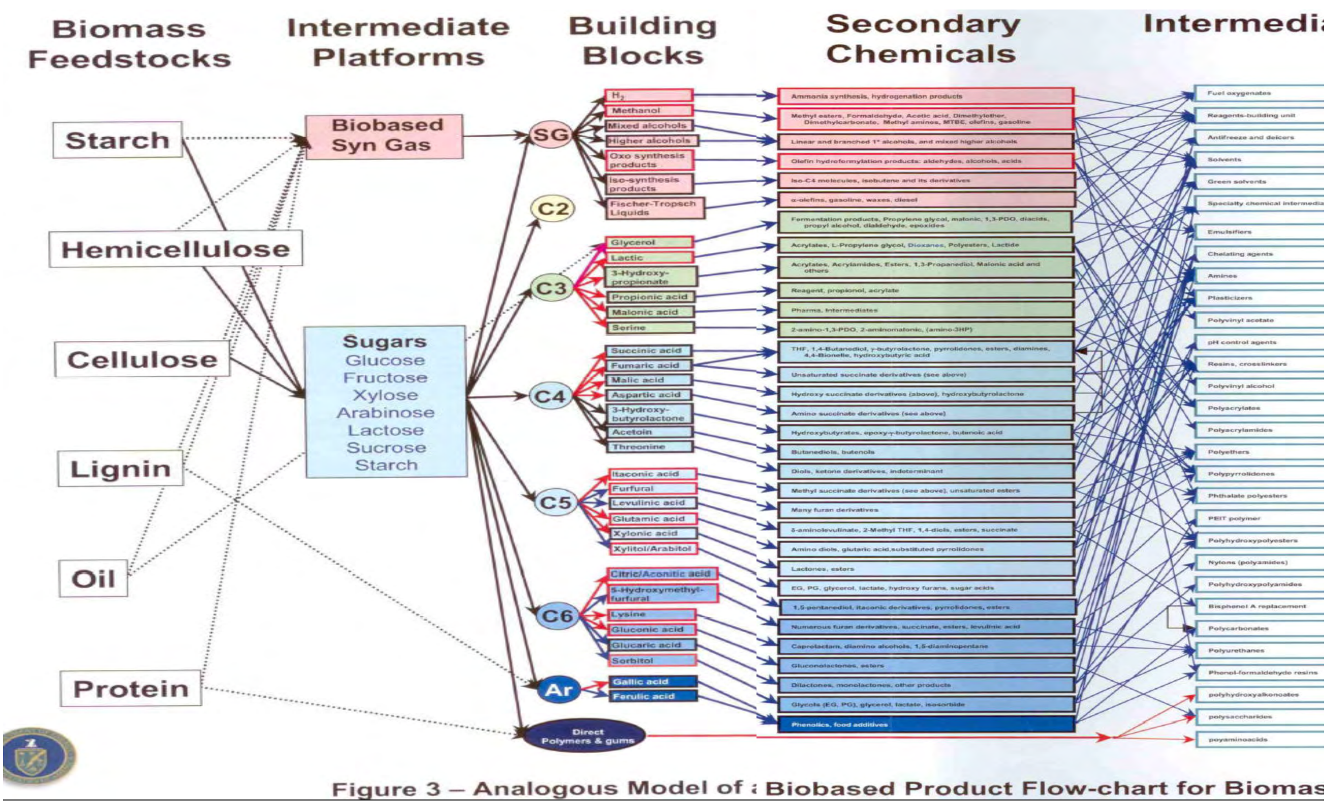
The US (Federal) government, large grain handling companies including Archer Daniel Midlands (ADM) and the national corn growers are collaborating in the provision of funding to PNNL to research fractionation and recovery of high value products from wet milling. After wet milling corn for ethanol production, the left over grain is normally sold as stock feed.

[32] Top value added chemicals from biomass Volume 1. US Department of Energy. Energy efficiency and renewable energy.

However, there are still C5 sugars, sterols, copherols and steriles that are worth (about) US$20/lb on the market that can be fractionated and recovered to be used in the chemical industry. Corn fibre is 40% C5 sugars, of which 90% can be extracted, 3% oil and 20% protein and cellulose. After these high value products have been extracted, the remaining product is approximately 50% of its original weight. However, as feed value is determined by protein content the value to the company is the same as pre-extraction. At the time of writing, PNNL advised that the economics of this are still at the pilot stage, but look promising.

This is one example from hundreds of potential niche opportunities for traditionally petroleum based products to be replaced with renewable sources. To illustrate the opportunities that arise from these types of processes, I have reproduced a diagram from "*Top value added chemicals from biomass – volume 1 – Results of screening for potential candidates from sugars and synthesis gas*" produced by the US Department of Energy. This reproduction is not very clear, however, the purpose of including it is to demonstrate the web of options and alternatives that are available for the replacement of petroleum products with bio-based alternatives.

Figure 7: pathways to secondary and intermediate chemicals from agricultural feedstocks



The uses for the intermediate by products are almost limitless and include:

- Industrial uses including: Corrosion inhibitors, dust control, boiler water treatment, gas purification, emission abatement, specialty lubricants, hoses and seals;
- Transportation uses including: fuels, oxygenates, antifreeze, wiper fluids, moulded plastics, car seats, belts, hoses, bumpers, corrosion inhibitors;
- Textile uses: carpets, fibres, fabrics, fabric coatings, foam cushions, upholstery, drapes, lycra, spandex;
- Safe food supply: food packaging, preservatives, fertilizers, pesticides, beverage bottles, appliances, beverage can coatings, vitamins;
- Environment: water chemicals, flocculants, chelators, cleaners and detergents;
- Communication: moulded plastics, computer castings, optical fibre coatings, liquid crystal displays, pens, pencils, inks, dyes, paper products;
- Housing: paints, resins, siding, insulations, cements, coatings, varnishes, flame retardants, adhesives, carpeting;
- Recreation: footgear, protective equipment, camera and film, bicycle parts and tyres, wet suits, tapes, CD’s DVD’s, golf equipment, camping gear boats;
- Health and hygiene: plastic eye glasses, cosmetics, detergents, pharmaceuticals, suntan lotion, medical-dental products, disinfectants, aspirin.

Of more immediate application are the alternative markets for mustard-seed meal by-product. The University of Idaho is currently working on niche markets for glucosynolates isolated from mustard meal. Currently 205 different glucosynolates with differing properties have been identified (dubbed ‘designer fumigants’). Isolates have proven to give exceptional control of nematodes (99.9% efficacy) and weeds. The mustard meal is also high in nitrogen which is utilised by crops in the following year.

Figure 8: Herbicide effects of glucosynolate in carrots (University of Idaho 2006)

After the removal of glucosynolates, mustard meal is very high in protein (41%). This has been taken advantage of by the fast food industry where it has been added to beef burgers to 40% of the content. Since yellow mustard meal is technically a spice, the labelling of the burgers has legally been “100% beef”…[33]

Processing crop oil for industrial uses, could be considered the production of “just another commodity”. However, the natural lubricity character of canola oil renders it superior to petroleum oil for many uses. This has given rise to the “biogrease” market. In conversation with Professor Jack Brown (University of Idaho), I learnt that canola oil is second only oil to whale oil in quality for transmission oil. There is a great opportunity to concentrate on the production of a superior product (all greases and oils). The key here is advertise the product superiority in terms of performance and the environment. One example is the use of rapeseed oil as chainsaw grease in environmentally sensitive areas (in this case, the Scandinavian forests). ½ pint of rapeseed oil (nearly exactly the same as canola oil) sells for USD $10 - $12.

[33] Jack Brown. Professor, Plant Breeding and Genetics, University of Idaho

The Oil Situation – will Renewables Eventually be Necessary?

Current and future demand for oil

In June 2006, The Energy Information Administration (www.eia.doe.gov) published an energy outlook for the World Oil Markets. The findings were that world demand is set to increase by 47% from 2003 to 2030 (43% of this increase in demand will be from non-OECD Asia, including China and India). This equates to a growth from 80 million barrels per day in 2003, to 98 million barrels per day in 2015 and 118 million barrels per day in 2030. Higher oil prices are expected to drive increased oil extraction in the non-OECD countries (62% of the increase). Prices are expected to be at US$57/ barrel (although there is uncertainty about this) in 2025 which is a 35% higher prediction than the previous year's report. The higher prices reflect lower levels of investment in key resource rich regions. Lower investment is justified by strong worldwide economic growth despite higher oil prices. Higher prices also reflect restrictions on access and contracting that affect oil exploration and production costs. The higher prices have two effects. They are likely to make previously uneconomic resources in non-OPEC regions more likely to be produced. The second result will be to increase the supply of non-conventional resources (including biofuels, gas to liquid and coal to liquid). The report states that in 2003, unconventional resources totalled only 1.8 million barrels per day. Supplies are expected to rise to 11.5 million barrels per day (10%) of total world petroleum supply in 2030.

According to the report, the transportation sector will be responsible for 50% of the projected increase in demand (greatest of any sector) since there are fewer competitive alternatives to petroleum for this sector. The industrial sector will account for 30% of the increase for chemical and petrochemical processes (see section on "…. For opportunities in the biomass industry").

Proven oil reserves are expected to meet demand for the period to 2030. Oil reserves were higher than previous reports (declining in some regions including North America and Europe). 71% of the world's supplies are located in the Middle East and Canada (Canadian oil sands). Peak oil is expected to be reached some time after 2030, however, this date is highly debated.

It should also be noted that this study assumed a "business as usual approach" with no disruptions to oil supply due to war, terror, weather or political reasons. Price susceptibility to adverse events was observed in the increase in oil price due to the gulf war and the further increase after cyclone Katrina in North America.

Alan Dupont (Senior Fellow in International Security at the Lowy Institute) sees Australia's oil supply as a concern as we are only 42% self sufficient and this percentage is declining. There are very few prospects of finding more oil reserves in Australia and we are the only member of the International Energy Agency (IEA)[34] that does not maintain a 90 day oil supply.

Will renewables be necessary?

It is apparent that renewables will not be necessary due to lack of oil supply before the year 2030. If oil alone is the criteria upon the necessity of renewable fuels in the economy, then it would be deemed unnecessary. However, with the advent of climate change and the consequent emissions that will be produced with this increase in demand for oil (not to mention coal…) as well as the knowledge that peak oil is in the foreseeable future. The lead time needed for the transition between oil and clean alternatives is conceivably shorter than the time that we have allowed. Renewables are necessary and will make a significant contribution to the energy supply in years to come.

Biodiesel And The Environment – NOx emissions

Benefits of biodiesel compared with fossil diesel

In terms of the environment, biodiesel is an improvement on fossil diesel in every respect except for emissions of NOx (gaseous compounds of nitrogen and oxygen). Tests results vary slightly in the exact measure of these benefits depending on the test conditions. To demonstrate the benefits of biodiesel over fossil fuel, I have used results from trials conducted by the Environmental Protection Agency of the United States (EPA) as presented by the National Biodiesel Board.

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[34] The IEA acts as an energy policy advisor to 26 member countries to help ensure reliable, affordable and clean energy. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world.

To view EPA's report titled "A comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions", go to: www.epa.gov/otaq/models/biodsl.htm.

The addition of biodiesel to fossil diesel has an exaggerated effect on reducing particulate emissions (sub 10 micron). In test conditions, B20 (20% biodiesel with 80% fossil diesel) reduced particulate matter up to 15%. The same blend reduced total carbon-monoxide to 20% and hydrocarbons by up to 30% (100% biodiesel reduces ozone forming hydrocarbons by nearly 50%). It is also important to note that biodiesel does not contain sulphur.

Biodiesel is also better for human health than fossil diesel. The reduction in particulate emissions is beneficial for those with respiratory complaints and the reduction of carcinogenic aromatic hydrocarbons (between 50% and 85% depending on the exact compound) is a benefit to the community as a whole. The product itself (100% biodiesel) is ten times less toxic to humans than table salt and is readily broken down in the environment (at a similar rate to dextrose sugar). All of these attributes make biodiesel a superior fuel in places that are heavily populated and/or environmentally sensitive.

The energy balance for biodiesel (that is the energy input: energy output) is also superior to that of fossil fuel. Although to what extent depends on the crop type and yield (growing season inputs distributed over oil yield), and freight of the raw product (i.e. life cycle analysis).

Variations in the energy return are as follows:

- 1:2.6 for rapeseed methyl ester – German lifecycle scenario[35].
- 1:3.21 for soy methyl ester in a U.S. situation [17] (the reason for the difference is less fertilizer inputs into soy legume than rapeseed or canola). This is a representative range for first generation crops.
- The use of waste products (used cooking oil) has a much higher ratio (1:5.51) since the lifecycle of crop production is not taken into account rather the transport and processing components only (alternative for used cooking oil is disposal).
- Finally, fossil diesel has a ratio of 1: 0.9 and 1:0.83 in Germany and USA respectively. Note that there is an energy loss. The cited reason for this is that "… up to 20% of the energy contained is used for fuel production with exploration of crude oil, refining process and transportation the major contributors to energy loss."[35]

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[35] Biodiesel – the comprehensive handbook. Martin Mittelbach and Claudia Remschmidt. 2005

An explanation of NOx and how to reduce it in biodiesel combustion

NOx is a class of gases formed by high temperature reactions between nitrogen and oxygen including nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O). While spark ignition engines emit NO as the major component of NOx, diesel (compression) engines emit 10 – 30% of the NOx as NO_2 with the balance being NO. NO is gradually converted to NO_2 in the atmosphere. While both of these chemicals are irritants, the main concern is smog formation at ground level and associated formation of ozone. This is a particular concern for people with respiratory problems. The other concern about NOx emissions is that they cause acid rain, with consequential environmental and building deterioration.

Cars powered by 100% biodiesel emit 4 – 13% more NOx than fossil diesel powered vehicles. NOx levels decrease proportionately as the percentage of fossil diesel in the blend increases. NOx emissions can be eliminated by retarding the engine's fuel injection by 1-2 degrees of the crankshaft angle (US Department of Agriculture technote). This modification would sacrifice a portion of the particulate reduction (although this would still be significantly better than fossil diesel particulate emission). The modification would also improve fuel efficiency, however, it means that biodiesel can not be sold on the basis that it requires no engine modification.

Other ways that the NOx emissions can be reduced in biodiesel are by recirculating the exhaust gas (this lowers the temperature of combustion), increase the cetane number of the fuel by using highly saturated feedstocks (this results in fuel igniting faster, reducing the amount of fuel in the self ignition phase and reducing the temperature).

Other Energy Opportunities for Farmers

Wind

The capital costs of wind farms usually put such a project out of reach for individual land owners. The concept of 'community wind' is one that is particularly popular in the United States. Such projects are aimed at retaining some of the value of the wind power in the rural area. As one of the main costs of establishing a wind farm is the transportation and setup of the turbines, communities or individual farmers can take advantage of the economy of scale of a proposed wind farm by purchasing 3–4 turbines (each capable of producing 3–7 MW). Another approach is direct investment in a wind farm that is already commissioned.

Royalties in the US are typically between US$2000 – US$5000 per year for each turbine (depending on size). These payments are in the form of a fixed annual lease payment, a single up-front payment, a share in the revenue from the wind project or a combination.

Anaerobic digesters

Anaerobic digestion is the process by which anaerobic bacteria (bacteria that live without oxygen) are used to breakdown volatile solids into acids which are then used to generate biogases (40% carbon dioxide and 60% methane). These gases are burned to produce electricity. Gas production is a four stage process of hydrolysis, acidification, acetogenesis and methanogenesis.

There are two types of reactors, batch and continuous. Batch is suited to the on-farm situation. The reactor is loaded with organic materials and allowed to digest (time depends on temperature and feedstocks). The by-products are then removed and the process is repeated. The second method is continuous (suited to larger processors) in which material is continuously fed into the digester where it moves through mechanically (or by being pushed by the addition of new feedstock).

On farm biogas production is popular in Germany and other highly populated regions where waste management is tightly controlled. Anaerobic digesters are effective ways to treat animal waste, municipal solid waste (eg green clippings or food), crop residues and waste waters (municipal or industrial). The final products include biogas which is generally burnt in the same way as natural gas for heat production or electricity which can be added to the grid. The solid waste is a nutrient rich soil conditioner (nutrients are readily available for plant use) and the liquid by product is used as liquid fertilizer.

Figure 9 right: Greenfinch anaerobic digester. Small scale process for home and garden wastes

Figure 10 (Left): Large scale continuous process. The electricity generated from this anaerobic digester provides 100% of the electricity requirement for an ethanol plant (Nebraska 2006).

Figure 11: Slats for collection of cattle waste. Slats minimize dirt contamination which reduces efficiency of the anaerobic digestion but life on slats takes a toll on animal health.

Biomass co-heat and power units

Combined heat and power systems are those in which biomass is burned to indirectly fire a gas turbine generator set. The system consists of a high temperature combustor a heat exchanger and a turbine generator. Ambient air is induced and compressed. The air is then heated by the biomass combustion via the heat exchanger. The heated and compressed air is then expanded in the power turbine transferring the energy to mechanical energy. The turbine converts the mechanical energy to electricity via an alternator generator. The exhaust gases are recovered to the combustor and the exhaust can be fitted with a waste heat boiler for transferring the heat energy to other uses. Utilisation of by-product heat substantially increases the efficiency of the system. Smaller units that are able to fully utilise the heat component are 20% + efficient which compares to a steam based system at 8 -10% efficiency (due to wasted heat). In the UK smaller stations (under 250kW) are beneficial in the sense that you can simply plug them in to a 3-phase power connection (£200 fee) to add electricity to the grid (this becomes more complicated with larger equipment).

Figure 12: turbine generator is part of a system that produces 100kW of renewable energy and 150 kW of renewable heat (saving 600t CO_2 per year). The system runs on a wide range of biomass fuels including wood chips and pellets, agricultural residue and coppiced willow. A 50kW unit needs a biomass input rate of 50–100kg per hour (depending on type and moisture content - biomass should be between 15–20% moisture).

A Word on Carbon Credits

Although this is not my particular area of study, it is worth a mention since there is much debate about the value of carbon trading in a global economy but not much explanation about how they actually work. It is impossible to consider the full value of production of biofuel without taking carbon credits into account.

The European system (discussed below in detail) is the most established system for trading carbon credits. In America, since the Federal Government will not commit the country to the system, individual states have taken it upon themselves to govern carbon trading, as they have with meeting the Kyoto protocol requirements. Carbon credits have started trading on the Chicago stock exchange.

The European system begins with an initial assessment of a company's annual carbon dioxide output. An allowance is then set for this company. The environmental benefit is realised as this allowance is reduced year by year. The company can increase it's carbon dioxide efficiency (reducing the emissions). If the company becomes very efficient, the difference between the permitted CO_2 output and actual output may be traded. Conversely, if the company is less efficient than the set standard, it must buy carbon credits from a more efficient company or project designed specifically for carbon absorption. If carbon dioxide excesses are not offset by credits, the company must pay a fine. The fine must be many times the cost of buying an offset to set a robust trading market for carbon credits (currently a fine is about three times the cost of a credit). There is a fear amongst some economists that the value of the carbon credit could be traded well above that of it's actual environmental value and be detrimental to the ability of carbon emitting companies to be viable. This has been addressed by world renowned Australian economist Warwick McKibbin. He proposes that the carbon credit be capped at AUD$10. However, the "Stern" report released October 2006 leaves no doubt that the price of ignoring emissions is far greater than any economy could tolerate. It also confirms the moral obligation of developed countries to act on their emissions, to see the Stern report,

http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

Conclusion

The challenge of biofuels is the development of innovative technologies and processes to encourage the industry to be competitive with fossil fuels while remaining environmentally sustainable. The concept of increasing 'miles per ha' is a driving force behind the adoption of second generation fuels in attempt to maximize energy production per unit area without threatening food production capability. This strategy also assists in the use of existing infrastructure and personnel where possible. There are some issues with current biofuels and the lack of ability to share fossil fuel pipelines (namely due to the lubricity of biodiesel and presence of water in the biofuels), however, future biofuels have the potential to utilize the existing infrastructure and logistics system.

From what I have observed on my scholarship, I believe fuel production will always be a large business and as a consequence, small scale production with exotic methodology and isolated feedstocks will rarely be viable in a developed economy. Industrial scale production carries a number of advantages including quality control.

The two key components to the viability and success of the biofuels industry in Australia are consumer acceptance of, and demand for biofuel together with a supportive legislative environment. Consumers expect similar vehicle performance, handling and mileage to fossil fuels. Cost needs to be on a par with fossil diesel, however, in Germany biodiesel is sold at a premium which was accepted by the consumer for environmental reasons. Legislation and funding need to be consistent and enacted strategically with a long term view to encourage investment in a stable business environment (as outlined in the Washington state case study). To date the most common forms of legislation employed in other countries are tax incentives, mandates and emission standards (with potential to lead to emission taxes and higher fossil energy prices). To promote the adoption of more CO_2 effective technologies, tax incentives should be based on the carbon balance of a production system (to better reflect the benefits to the environment).

Feedstock supply and proximity to processing facility are important considerations. Australia has a unique opportunity with large amounts of sunlight and marginal land that cannot currently be used for food production, but which may be viable for the production of biofuel crops.

Biofuels are an important tool in the race to abate climate change. With proper planning and careful management the existing land use competitors of food, feed and fire should be extended to food, feed, fibre and fuel. Increased land use competition will better reflect the true (environmental) cost of production, lifting the value of all products. With local investment, a new industry in the agricultural sector will give rise to an opportunity for increased and distributed rural wealth, employment opportunities and improved environmental status of farming.

Disclaimer: This report is a result of my study and represents my findings and opinions which are not necessarily those of the Nuffield Farming Scholarships Trust or of my sponsor. To the best of my knowledge the information presented is accurate at the time of writing (October 2007).