Economics & Markets Research

ANZ industry report: biofuels

Biofuels are now mainstream and multinational. The next development stage is at hand.

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Inside:

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Our Vision:

For Economics & Markets Research to be the most respected, sought-after and commercially valued source of economics and markets research and information on Australia, New Zealand, the Pacific and Asia.

Key points

Since we last examined the (then) emerging market for biofuels in 2005, biodiesel and fuel ethanol have matured into mainstream, multinational products. Factors supporting their rapid development have included:

- strong price rises for all transport and energy fuels, with global demand growth outstripping readily available supplies;
- rapidly developing biofuel production technologies and applications;
- strong government support for biofuel production and consumption in the EU, US and increasingly, other countries;
- environmental concerns about the climate effects of fossil fuels, and
- the imminent rise of the 'carbon economy' age, in which CO_2 emissions will be widely measured, priced and traded.

In the second half of 2008, global financial markets — and, more crucially for biofuels, global commodity prices — are falling radically and rapidly. As for other energy commodities, the economics of producing biofuels in this new post-boom period now seems less certain and potentially more difficult. The 'green' credentials of biofuels have also come under fire, particularly regarding their energy efficiency, pollution emissions and effects on third-world food producers and their environment. In response, the EU is now reviewing the extent of its considerable support for biofuels.

Looking forward, there are still many positives to support biofuels' development, including: 'second generation' feedstock sources, production methods and technologies; growing biofuel production and demand hubs in developing countries; and widespread government support for biofuel production and consumption. On current trends, the OECD and FAO expect global biofuel consumption to grow by at least 5% p.a. to 2017.

Biofuels — some definitions

'Biofuels' are any transport fuel made from organic, renewable materials.

Ethanol is a type of alcohol. It is produced by fermenting and distilling sugar and starch found in plants such as corn (maize), sugar cane, wheat, sorghum or canola (rapeseed). Ethanol can also be made from woody plant fibres (crop waste, grasses and trees), seaweed, algae, organic waste and even household waste. Production from these sources is still in the research phase and yet to be developed on a commercial scale.

Ethanol comes in various grades and is a common ingredient in solvents, perfumes, varnishes, disinfectants and beverages. **Fuel-grade ethanol** can almost wholly replace petrol (E85) in modified petrol engines or it can be blended with petrol (E5 to E10) to run in unmodified petrol engines.

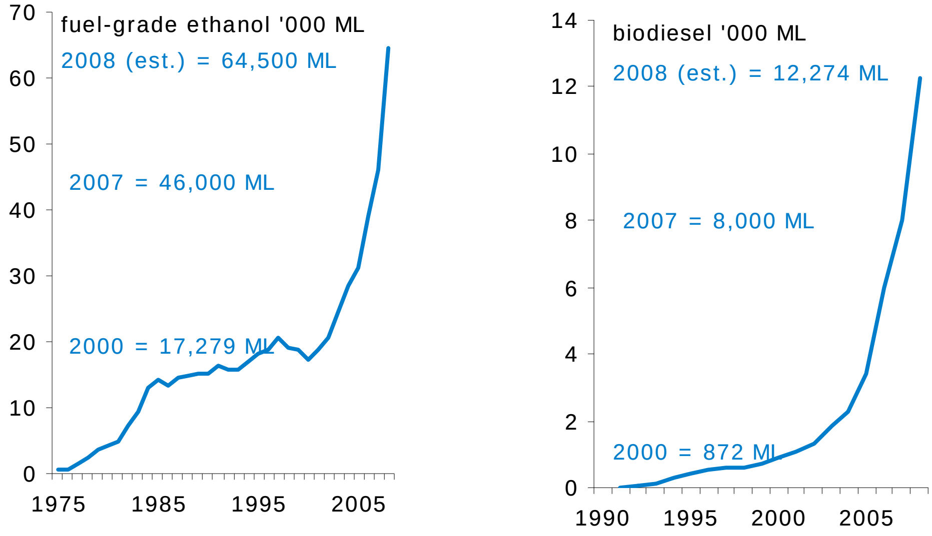
Biodiesel is produced from vegetable oils (or less commonly, animal fats) using a process in which the oil is reacted with an alcohol such as methanol or ethanol in the presence of a catalyst. Potential sources of biodiesel include new or used vegetable, canola (rapeseed), soybean, sunflower seed or palm oil, tallow, lard or yellow grease. Biodiesel can be used as a replacement for diesel in modified (and some unmodified) diesel engines or blended with diesel for use in conventional diesel engines.

Biofuel production trends

Commercial biofuel production has exploded since 2000

Both ethanol and biodiesel have been used as transport fuels for several decades (most notably ethanol in Brazil), but commercial production of biofuels did not begin to really accelerate until around 2000. Since then, biofuel growth has been dramatic. Fuel-grade ethanol production grew by 166% from 2000 to 2007, while biodiesel production grew by 817%, albeit from a very small base. Further growth of 40% (ethanol) and 53% (biodiesel) is expected in 2008 alone.

Figure 1: Annual world commercial production of ethanol and biodiesel



Sources: Worldwatch Institute 2008 (1975-2007 data); OECD-FAO 2008 (2008 estimate)

Ethanol and biodiesel are located in different markets, reflecting the dominant transport fuel (petrol or diesel) in different countries and the biofuel source crops available to them. Ethanol is produced and consumed primarily in Brazil and more recently the US. Biodiesel is more popular in Europe and southeast Asia, reflecting their greater reliance on diesel for transport and energy. China and other Asian countries are rapidly increasing production of both biofuel types.

Ethanol production

Ethanol production and consumption is still mainly located in the Americas,

but ethanol production is growing elsewhere too

The US and Brazil produce over 90% of the world's fuel-grade ethanol (and all of it a decade ago). Other countries now producing ethanol include the EU, Canada, China, India, Thailand and Australia. China is now the third largest producer of ethanol, with volumes far behind the US and Brazil, but is growing quickly.

The most common source crops for ethanol are sugar cane (Brazil), sugar beets (EU), corn (US) and other grains (China, Canada, Australia and elsewhere). Of these, sugar cane is the most efficient source crop, producing an average of 6,000L of ethanol per hectare, compared with around 5,000L from sugar beet, 3,000L from corn, around 2,500L from wheat and just over 1,000L from barley.[1]

Figure 2: World fuel-grade ethanol production

million litres (ML)	1986	1996	2006	2007	*2008 (est.)*
Brazil	10,506	14,438	15,700	18,999	*22,110*
United States	2,687	4,164	18,300	24,605	*38,394*
TOTAL WORLD	**13,193**	**18,750**	**38,200**	**46,000**	***64,517***

Sources: Worldwatch Institute 2008; OECD-FAO 2008.

[1] Worldwatch Institute 2006, p. 8.

Fuel-grade ethanol now contributes 5.5% to global petrol/gasoline fuel energy output

Global ethanol production for all purposes has been growing rapidly in recent years, but demand for fuel-grade ethanol is the major cause. The OECD-FAO estimates that global total ethanol production jumped from 50,284 ML per year from 2005-07 to 77,054 ML in 2008, with the share of this production going into transport fuel increased from 79% (39,811ML) to 82% (64,517 ML). As a share of the world's total petrol/gasoline type fuels by energy output however, ethanol is minor but growing, at just 5.5% in 2008 (up from 3.4% for 2005-07).[2]

Historically, **Brazil** is the world leader in ethanol production and consumption, with strong government support dating back to the first oil crisis in the 1970s. Currently, about 75% of Brazil's light vehicles (passenger and small commercial) are 'flex-fuel' cars that can run on E85 (85% ethanol) and a minimum E20 blend is mandatory. Brazil's ethanol production from sugar cane is more efficient than any other current production method; it is the only one that beats US gasoline on price (see figure 6 below) and Brazil is the only country that has exports fuel-grade ethanol in significant quantities (to the EU, US and Canada).

The **US** (like Australia) has a long history of dabbling in ethanol as a transport fuel[3]. But the current trend toward large-scale commercial production from corn crops only commenced in the late 1980s, with relatively low volumes (under 5,000 ML p.a.) until 2000. Since then, active US government support at state and federal levels (see discussion below) has seen US corn-based ethanol production soar. The US overtook Brazil's ethanol production (by volume) in 2005, reaching 24,600ML in 2007 and an expected 38,400ML in 2008.

Canada has introduced similar support measures and is also increasing fuel-grade ethanol production from grains. Canada produced just 762ML per year in 2005-07 but the OECD-FAO expects it to produce 1,383ML in 2008.

Outside the Americas, **Europe** collectively produced around 2,000ML of fuel-grade ethanol per year from 2005-07, rising to an expected 4,400ML in 2008. The EU's consumption of ethanol is greater, since it also imports from Brazil. EU ethanol production is currently more expensive than others (see figure 6 below).

China also increased its fuel-grade ethanol production in 2008 to 2,139ML, up from 1,565ML annually for 2005-07. Total Chinese ethanol production is much higher (6,686ML), with the majority still produced (and exported) for purposes other than transport fuel. Likewise, **India** will produce an estimated 1,909ML of ethanol from a variety of crops in 2008, but only 416ML of this will be consumed as transport fuel. India is increasing sugar cane ethanol production significantly. **Thailand** will produce 400 ML of ethanol from sugar cane, 230 ML of which will be fuel-grade. The Thai government aims to increase this total production to 3ML per day (over 1,000ML per year) by 2011, just 3 years away.

Australia has also increased its ethanol production with government support, but progress has been slow due to drought, high sugar and grain prices and reluctant Australian car drivers. All ethanol produced commercially in Australia is used locally as a petrol additive (E5 or E10). Australia produced an average of 63ML per year from 2005-07 but is expected to produce 156 ML in 2008.

Biodiesel production

Biodiesel now contributes 1.5% to global diesel fuel energy output

Biodiesel production has mainly been a European story to date, but it is now rapidly becoming an Asian one also. Globally, biodiesel replaces a smaller share of diesel-type fuels than ethanol does for petrol/gasoline, at just 0.93% of global diesel fuels' energy output in 2005-07 (annual average) and 1.5% in 2008.

Biodiesel production and consumption is centred on Europe, the US and increasingly, Southeast Asia

Four of the five biggest biodiesel producing nations are in **Europe** — Germany, France, Italy and Austria —, but the **US** is the single largest producer. **Brazil** also produces small but growing quantities of biodiesel (760 ML in 2008, up from 160ML in 2005 to 2007), as does **Australia,** which is expected to produce 910ML in 2008, up from just 200ML annually in 2005 to 2007.

[2] OECD-FAO 2008, p. 71.

[3] See *ANZ Industry Brief – Automotive Biofuels*, Dec 2005.

Figure 3: World biodiesel production

million litres (ML)	1986	1996	2006*	2007*	*2008 (est.)*
EU (27 nations)	0	546	5,095	5,095	*6,580*
United States	0	0	1,429	1,429	*2,017*
TOTAL WORLD	**0**	**546**	**7,610**	**7,610**	***12,274***

* 2005-07 annual average.
Sources: Worldwatch Institute 2008; OECD-FAO 2008.

Among biodiesel sources, palm oil is the most efficient 'first generation' crop being used, producing an average of around 4,500L of biodiesel per hectare. Other common source crops include canola, sunflower seeds and soybeans, but these typically produce only 800 to 1,200L of biodiesel per hectare.[4] European biodiesel is produced from the relatively less efficient canola (rape seed) and sunflower seeds, while Asian biodiesel is mainly derived from palm oil.

In Asia, the biggest biodiesel producers are currently **Indonesia** and **Malaysia**, with India running a close third. Prior to 2005, Malaysia was the biggest Asian biodiesel producer, but in 2008 Indonesia is expected to produce 753ML of biodiesel 2008 and Malaysia is expected to produce 443ML. Both rely on palm oil as their primary source crop, but also use jatropha, cassava and sugar cane. Their biodiesel exports to the EU are growing, with 20% of the EU's biodiesel consumption now coming from Asian soy and palm oil sources.

Indonesia's biodiesel expansion has been rapid but has been dogged by a lack of clarity around regulations as well as increasing raw material costs. Malaysian policy is further developed. It launched a National Biofuel Policy in March 2006 and a Biofuels Act in early 2007. By the end of 2007, Malaysia had issued just over 90 permits to produce biofuel, with 5 licences already were operational. Another 19 biodiesel plants were expected to be operational by the end of 2008, processing over 1.5 mn tonnes of crude palm oil as feedstock.

In **India**, the National Biodiesel Mission has targeted biodiesel to meet 20% of the country's diesel requirement by 2011-2012, using Jatropha Curcas oilseeds (a non-food crop). This target is extremely ambitious, given that only 317ML of biodiesel was produced in 2008, meeting less than 0.9% of the country's diesel-fuel type energy needs.

Thailand has also set itself ambitious medium-term biodiesel targets, aiming for 8.5ML of biodiesel production per day by 2012 (or 50% more than the US's current biodiesel production levels). Thailand is expected to produce 48 ML of biodiesel in total in 2008, from palm oil and cassava.

In **China**, the biodiesel industry is far less developed than for ethanol, with minimal commercial production at present (estimated to be less than 0.2 ML). Future growth potential is strong however, given China' s seemingly rapacious hunger for energy from all sources.

Elsewhere in Asia, the Finnish company Neste Oil is building the world largest biodiesel plant in **Singapore.** It will be operational by mid-2010, with an annual capacity of 800,000 tonnes. This will take Singapore's annual biodiesel output over 1 mn tonnes by 2010 and 3 mn tonnes by 2015.

In the **Pacific**, biodiesel is potentially — but not yet actually — in production. The commercial palm oil production is limited to the Solomon Islands and PNG, where plantations are well established. Copra is also a significant Pacific crop that has potential for conversion to biodiesel. Production of copra however, has remained at a subsistence level in most countries, waxing and waning with global copra prices. Few Pacific islands currently have any commercial oil processing capacity. Vanuatu has the biggest copra-crushing facility in the Pacific, with smaller commercial processing operations also available for palm oil, copra and coconut oil in the Solomon Islands, Timor-Leste, Samoa and PNG.

[4] Worldwatch Institute 2006, p. 8.

Current issues and risks for biofuels

The market for biofuels is being shaped and influenced by several key factors:

- Price and availability of biofuel source crops and production costs
- Price competitiveness with conventional petroleum-based transport fuels
- Government support and regulation
- Environmental and community effects of biofuels.

Biofuel 'first generation' source crops and production costs

1% of available arable land produced biofuels in 2004

This may have already doubled to 2% by 2008

'First generation' biofuels are currently made from a wide variety of crops, almost all of which are also used as food sources. The FAO has estimated that in 2004, 13.8 million hectares, or 1% of the world's available arable land, were being used to grow crops for biofuels. Total global output of biofuels more than doubled between 2004 and 2008, from 30,700 ML to an estimated 76,000 ML. So, even though the efficiency of biofuel production is also improving, it is likely that the proportion of arable land producing biofuels approximately doubled also, taking the total to 2% of all arable land by 2008. FAO data indicate that the proportion of land devoted to biofuel production is highest in the US (1.9% in 2004), EU (1.2%) and Latin America (0.9%) and will rise further globally.

World food commodity prices soared in 2007-08,

driven by a range of complex, coincidental factors,

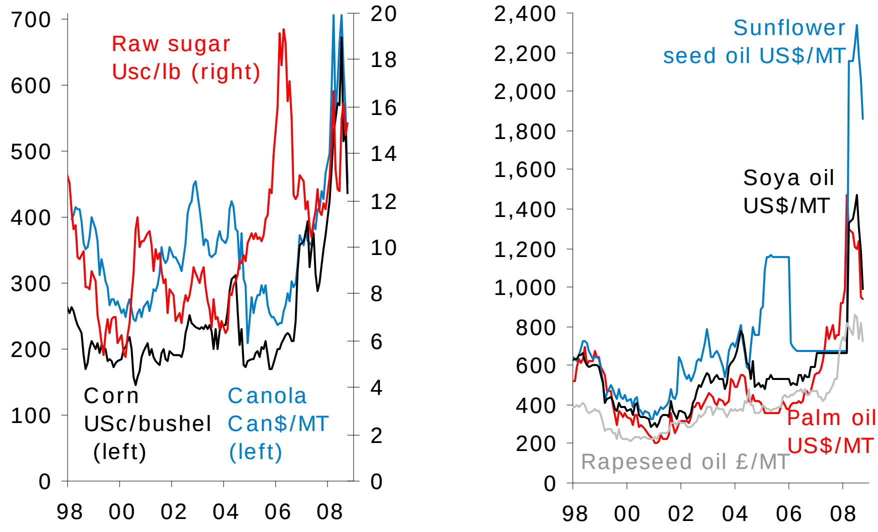
but prices have since come down from their peaks

This rapid growth in biofuel production — and displacement of crops for food — was widely blamed for soaring prices for many food commodities (especially corn/maize) through 2007-08. High food prices have led to demonstrations and even riots across several countries and prompted warnings from the UN and others on the (unforseen and unintended) consequences of promoting biofuel production at the expense of food production. At a major UN conference on food issues in June 2008, the UN's FAO concluded that biofuels were not all to blame:

> *"Biofuels are only one of many drivers of high food prices: weather-related production shortfalls in major exporting countries, low global cereal stocks, increasing fuel costs, the changing structure of demand associated with income growth, population growth and urbanisation, operations on financial markets, short-term policy actions, exchange rate fluctuations and other factors also play a role."* (FAO 2008, p. vii)

Importantly, prices for many biofuel grain and oilseed crops have followed other commodity prices down from their peaks since August 2008, as some of the factors noted by the FAO have unwound (see figure 4). Sugar prices peaked much earlier, in 2006. Prices remain elevated however, by historical standards, with growing demand for biofuels providing at least some of the price support.

Figure 4: Biofuel 'first generation' source crop prices have peaked — for now

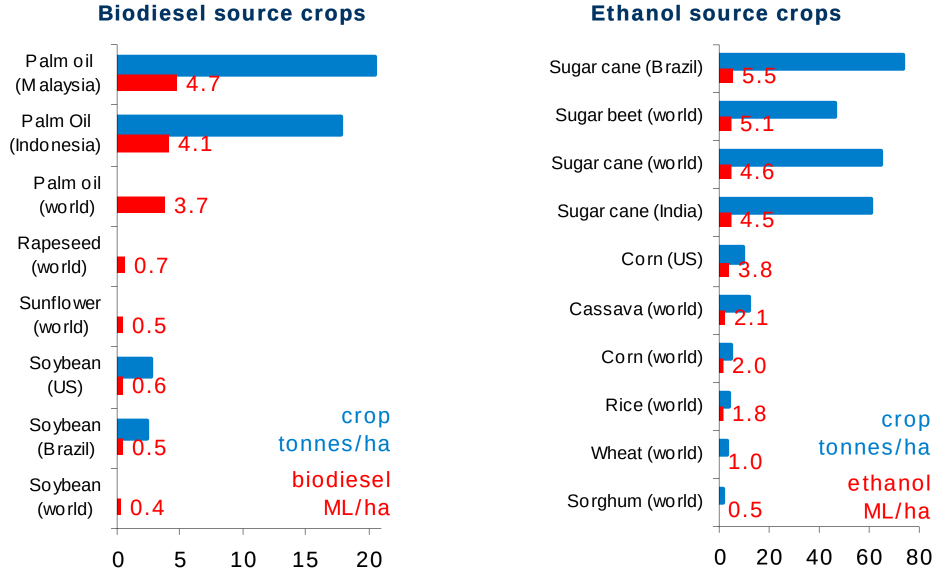


Source: Datastream (prices to Oct 2008)

Of the currently available source crops, Brazillian sugar cane and Malaysian palm oil have the best biofuel yields

Biofuel yields —and total production costs — from each source crop vary significantly. Of the current source crops, Brazillian sugar cane has the highest yield and lowest production costs for ethanol, while palm oil has the highest yield for biodiesel (see figure 5). These more efficient source crops are best suited to warmer climates, leading some commentators to conclude that biofuel production is less suited to temperate areas such as the US and EU, where biofuel production is currently concentrated, using less efficient source crops.

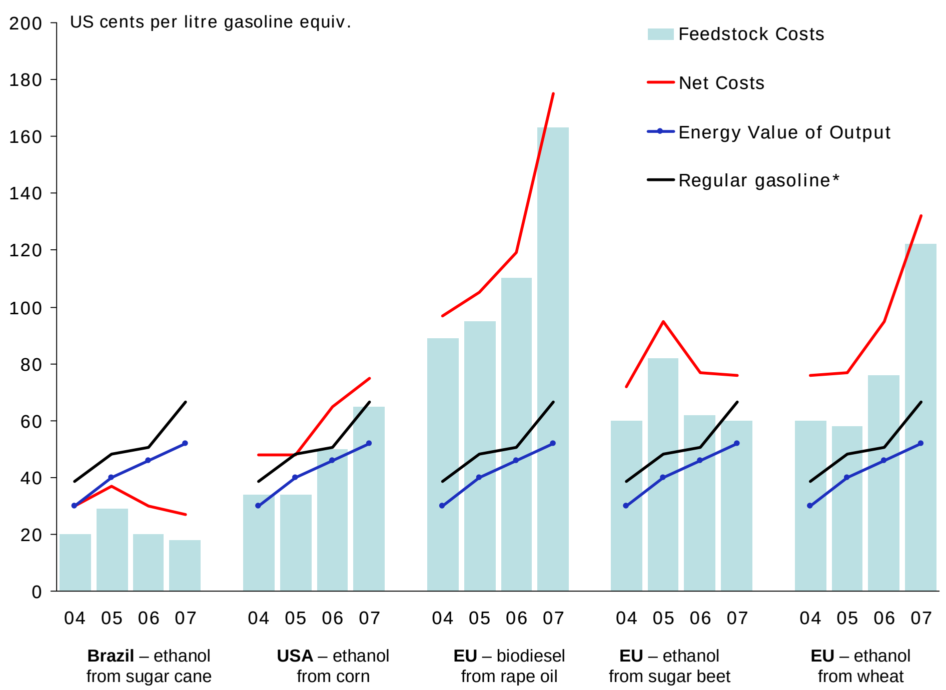
Figure 5: Biofuel 'first generation' source crop yields vary widely



Source: OECD-FAO 2008; FAO 2008.

Among the established biofuel producers, Brazilian ethanol from sugar cane has the lowest production costs

Figure 6: Production costs for 'first generation' biofuels, 2004-2007



Net costs = production costs (energy, processing and feedstock costs) less the value of any co-products (e.g. flour, sugar or feedlot grains)
* US regular conventional retail gasoline price, US cents per gallon, converted to US cents per litre (1 gallon = 4.54609 litres), end of year.
Source: OECD, EIA and ANZ Economics and Markets Research

Brazilian sugar cane ethanol is already price competitive with US retail gasoline

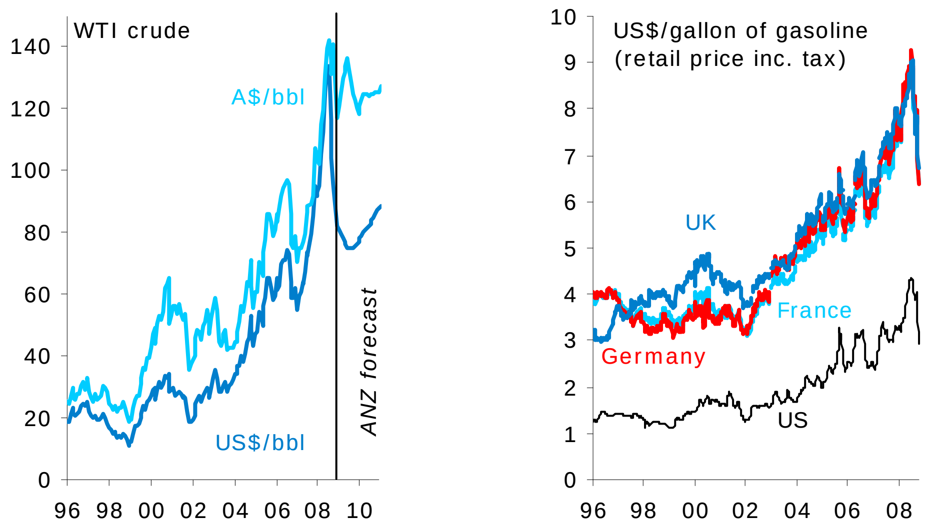
Among the established biofuel producers, Brazilian ethanol production from sugar cane is the most efficient in terms of feedstock and net production costs. It is also the only established non-Asian biofuel for which net production costs are *lower* than US retail gasoline prices, and for which feedstock costs fell rather than increased between 2004 to 2007 (with the price peaking in 2006). Net production costs are highest for European biodiesel from rapeseed and ethanol from wheat, exacerbated by high crop prices through 2007 (see figure 6).

For the newer biodiesel source of Asian palm oil, one of the governments' policy motivations behind establishing biofuels production in Asia was to help stabilise global prices for palm oil by diversifying its use. In 2007 however, palm oil rose by close to 60% (over US$1,000/t), exacerbated by high crude oil prices, but it is now back under US$500/t.

Price competitiveness with petroleum

Rising prices for biofuel source crops were of course matched — or even outdone — by rising prices for petroleum through 2007-08. As with food commodities, oil prices are now coming down again, but remain elevated by historical standards (see figure 7). Oil prices are crucial to evaluating the economics of biodiesel production, since a high oil price makes biofuels more profitable. In 2006, before the recent price spikes for virtually all the relevant commodities, the FAO calculated the oil price points that enabled viability for various types of biofuels. It found that based on average 2006 crop prices, Brazilian sugar cane ethanol was competitive at an oil price of around US$30bbl, while US corn (maize) ethanol required an oil price over US$58bbl and European production required an oil price over US$80bbl. These 'breakeven' prices are, of course, relative to the crop price; at an oil price of US$60bbl, US ethanol producers could afford to pay US$79/t for maize, but at US$100/bbl, they could pay up to US$162/t.

Figure 7: oil and retail petrol prices have peaked, but remain relatively high



Sources: RBA (monthly data to Sept 08); IEA (weekly data to end 20 Oct 2008); ANZ.

Since 2007, the interaction between high and volatile oil prices and source crop prices have made these calculations of 'viability' and 'competitiveness' less stable. FAO analysis of oil prices and source crop prices for 2004 to 2008 found that maize and oil price movements meant US ethanol production (the cheapest current US production method) was rarely price competitive with petroleum without subsidies, and was sometimes uncompetitive even with the subsidy.[5] Because they are direct energy substitutes, fuel ethanol and biodiesel prices have risen with petroleum and natural gas prices. The FAO found that the prices of major biofuel source crops consistently tracked oil prices upwards. This has

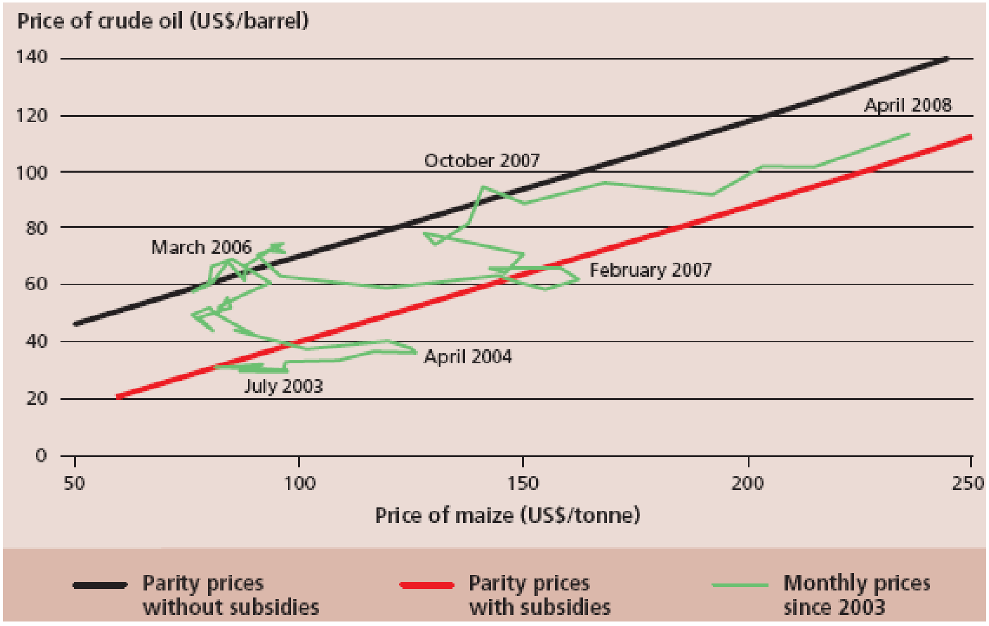
[5] FAO 2008, p. 36.

meant that US corn ethanol production costs are generally too high to enable (unsubsidised) price parity with crude oil (see figures 8 and 9).[6]

High prices for maize and natural gas (gas makes up 30% of US ethanol's variable production costs) have also caused gross margins for US corn ethanol production to fall significantly over the past two years, from 0.7 in 2006 to nearly zero by June 2008[7], even as ethanol prices climbed (see figure 10).

US corn ethanol is not price competitive with gasoline at most oil and corn price points, without government subsidies

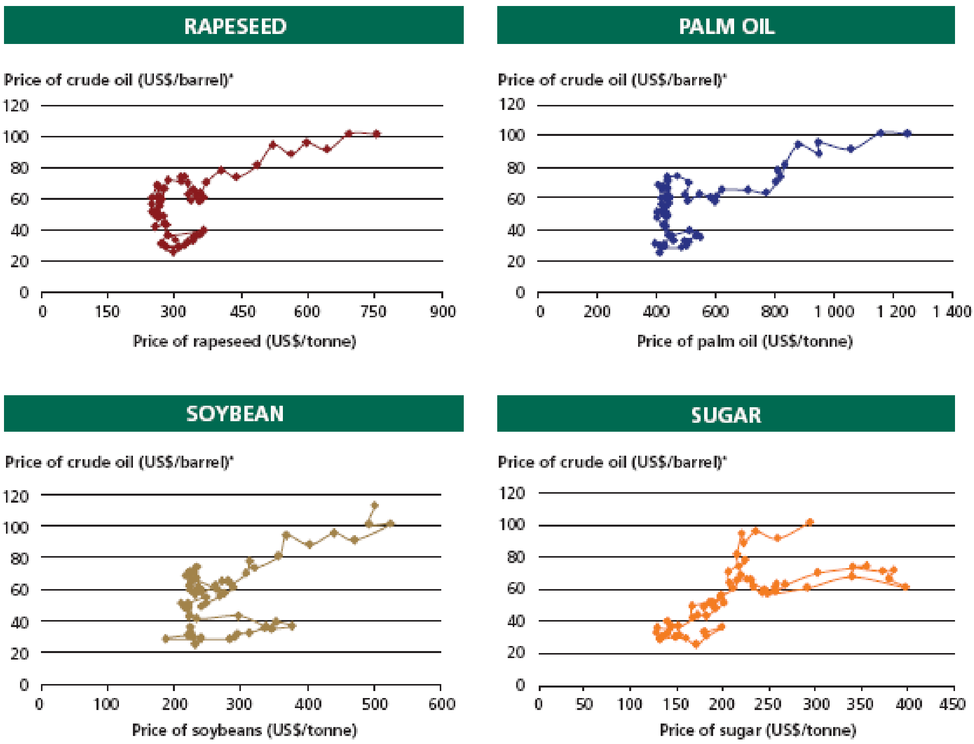
Figure 8: US corn ethanol and oil 'price parity' wholesale prices, 2003-08



Source: FAO 2008 (Brent crude oil and US Yellow No 2 maize, data to June 2008).

Biofuel source crop prices have followed oil prices up in recent years — as have almost all commodity prices

Figure 9:, Relationship between oil and biofuel source crop prices, 2003-08



Source: FAO 2008 (data to June 2008).

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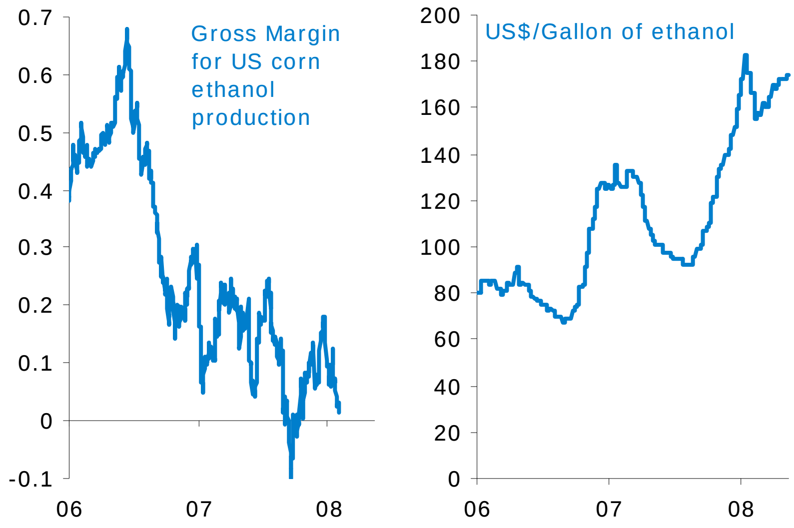
[6] FAO 2008, pp. 36-8.

[7] Estimated by ANZ Commodities Research.

Figure 10: US dry mill corn ethanol margins crash, but ethanol prices soar



Sources: Bloomberg and ANZ Commodities Research.

European ethanol and biodiesel production costs are even higher than US corn ethanol, but so too are EU retail fuel prices (see figures 6 and 7). These results reinforce the importance of government subsidies to support US and EU biofuel production (see discussion below).

Biofuel production in warmer and developing countries has better potential to be price competitive with petroleum

Outside the US and Europe, the relative production costs for biofuels look better. As noted above, Brazilian sugar cane ethanol is already efficient enough to be price competitive with US retail gasoline prices, which are among the lowest retail fuel prices in the world. In Malaysia and Indonesia, the high yield of local palm oil production is a great advantage. In India, a 2006 UNCTAD report[8] found that local ethanol from sugar cane and biodiesel from jatropha seeds had similar net production costs to petrol and diesel, at around US$0.47/litre. Indian biodiesel production has not expanded greatly since then, but falling sugar prices and the use of non-edible oilseeds such as jatropha, may make Indian biofuels look increasingly attractive against ongoing higher food and oil prices. India is actively promoting sugar cane ethanol production for domestic fuel use.

Looking forward, the WTI oil price fell below US$100/bbl again in October 2008 and is expected to retain a price of around US$75 throughout 2009 (see figure 7) as global economic growth slows down, taking demand for energy and fuels down with it. Biofuel source crop prices are falling back from their peaks also (see figure 4), but the price competitiveness of 'first generation' biofuels relative to petroleum seems likely to remain marginal at best, at least in the US and EU.

More positively however, rapidly developing biofuel research and new technologies — including exciting prospects for significantly cheaper (and greener) 'second generation' biofuels — will eventually reduce the cost of all biofuel production. In contrast, petroleum is a mature technology with fixed sources of supply and production costs. These cost competitiveness equations are therefore expected to move in biofuels' favour over the longer term.

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[8] UNCTAD, "An Assessment of the Biofuels Industry in India", October 2006.

Government support and regulation

"There is an urgent need to review current policies supporting, subsidising and mandating biofuel production and use." (FAO 2008)

Current government support and regulation promotes more biofuel production in the US and EU

Throughout their short history, biofuels have been heavily promoted and supported by government regulation and subsidies. As discussed above, current biofuel production is not viable in the US or EU without government subsidies. In Brazil, ethanol production is well established and self-supporting, after decades of past official support. In Asia, some palm oil biodiesel is competitive with oil; the industry is in its infancy and governments are keen to support it. The FAO has concluded that current government polices are promoting inefficient biofuel production in the US and EU and may be promoting production in Asia and elsewhere that is undesirable for environmental or other reasons. The UN is therefore calling for an urgent review of government biofuel policies worldwide.

The UN is calling for all countries to review their support of biofuels, urgently

Current government supports for biofuels are summarised in figure 11 below. Existing types of support include: trade tariffs; subsidies to agricultural and biofuel producers; retail price subsidies; tax credits and concessions; mandated biofuel blends; production and consumption targets; and dollars for research.

As a general rule of thumb, policies and subsidies aimed directly at increasing production or consumption levels are the most market-distorting measures, while support for research and development are the least distorting. Import tariffs are imposed by the US, EU, Australia, Canada and others to promote local biofuel production, even though cheaper biofuels are available from Brazil and elsewhere. Such tariff protection (like all agricultural tariffs) is aimed primarily at supporting local agriculture and rural development rather than at promoting biofuel production *per se*.

Globally, government support for biofuels is worth at least US$11bn per year

The FAO estimates that the total value of direct government support of biofuels was worth US$11.3bn in 2006 alone, US$6.3bn of which came from the US and $4.7bn of which came from the EU. More support came from general agricultural support programs (such as the EU's Common Agricultural Policy and US Farm Aid) and from state and country government programs for local projects.

To date, only the EU has acted on the UN's call to review biofuel policy, although prior to that, China imposed its own limits on the expansion of grains-based ethanol plants in late 2006, due to similar concerns about the effect on grain prices and local food sufficiency. The Chinese Government has since encouraged the use of non-staple crops such as sorghum, cassava and sweet potato for biofuels and has expanded non-grain biofuel production facilities in Inner Mongolia, Guangxi Zhuang, Hebei and Shandong.

The EU has reviewed its biofuel support policies

EU targets will now require more '2nd generation' biofuels and other green transport sources, and less '1st generation' biofuels

In the world's biggest biofuel market, the EU, as recently as January 2008, the EU was confirming its mandatory biofuel consumption targets of 2% of all transport fuels (by volume) in 2005, 5.75% in 2010 and 10% by 2020 for its member states, and added 'sustainability criteria' to deter investment in environmentally harmful biofuels. But in September, the EU Parliament agreed to amended its targets from 5.75% by 2010 down to 5% by 2015, and to specify that at least 20% of the 2015 target (5%) and 40% of the 2020 target (10%) must be from "non-food and non-feed competing second generation biofuels and/or from green electricity or hydrogen sources".[9] This amendment effectively reduces the targets for 'first generation' biofuels to 4% by 2015 and 6% by 2020. These targets still imply significant growth in EU consumption of all types of biofuels however, since total EU transport fuel consumption continues to grow steadily. The new targets will also apply to the EU's newer member states in the eastern half of Europe, growing the biofuels market even further.

[9] EurActiv.com News Netwrok, "Biofuel-makers denounce target downgrade", www.euractiv.com, 12 Sept 2008.

Figure 11: Current government supports for biofuels

Country	Production and consumption targets	$ grants, subsidies, credits
Australia	350 mn litres production by 2010 E5 and E10 available in some states	Fuel excise discount Production grants
Brazil	E22 mandatory in all petrol sales since 1993 B3 mandatory by 2008 and B5 by 2013	Discounts for flex-fuel vehicles
Canada	E5 in all petrol by 2010 B2 in all diesel by 2012	Fuel tax discounts
China	6 mn tonnes production by 2010 15 mn production tonnes by 2020 including 5mn tonnes of biodiesel by 2020 15% of transport fuel consumption by 2020	
EU*	2% of transport fuel consumption by 2005 5% by 2015 (20% of which to be 2nd gen or green elec.) 10% by 2020 (40% of which to be 2nd gen or green elec.)	Fuel tax discounts/exemptions. Common Agricultural Policy aid of up to €45/hectare for biofuel crops. Grants for production.
India	E5 available in some states from 2003 E5 available in all states from 2006 E10 available in all states from 2008	
Indonesia	5.29 mn KL production by 2010 9.84 mn KL production by 2015	
Japan	Production equivalent to 500 ML of crude oil by 2010	
Malaysia	5% biodiesel consumption for government vehicles by 2010, followed by public transport, then all private vehicles	
Thailand	E10 and B10 available nationally by 2012	
South Africa	8% of transport fuel consumption by 2006 10% target under consideration	
US *Iowa*	Biomass Research and Development Act 2000; 2002 Farm Bill; Energy Policy Act 2005; Energy Independence Act 2007; 9 billion gallons production by 2008 36 billion gallons by 2022 (including 21 billion gallons from 'advanced' biofuels) 10% of gasoline volumes by 2009 25% of gasoline volumes by 2020	Since 2004 - income tax credit for biofuel producers of 51c/gallon ethanol (48c from May 2008), $1/gallon biodiesel and $1.01 for cellulose ethanol. US$500 mn p.a in production grants from 2008 to 2015. $200mn for refuelling systems.

* Consumption targets agreed by EU Parliament, as of September 2008. Some EU members have additional intermediate targets and other local support measures.
Sources: Steenblik 2007; FAO 2008; EurActiv.Com News Network.

Environmental effects

> *"Biofuels will offset only a modest share of fossil energy use over the next decade … the impact of biofuels on greenhouse gas emissions varies widely, depending on where and how the various feedstocks are produced. In many cases, increased emissions from land-use change are likely to offset or even exceed the greenhouse gas savings … There are many concerns and challenges to be overcome if biofuels are to contribute positively to an improved environment"* (FAO 2008, p. vii)

After an initial rush of optimism, concerns have steadily grown over the environmental benefits of biofuels over fossil fuels. These doubts have the potential to significantly undermine the case for government support of biofuels, given that environmental effects were a key reason for government promotion of biofuels in the first place. Environmental concerns about biofuels relate to:

1. net greenhouse gas emissions (GHG) of biofuels, taking into account the fuels they replace, crop production and any associated land-use change; and

2. the effects of biofuel crop production on local agriculture, biodiversity, rural communities and food supplies, particularly in developing countries.

The net environmental benefits of biofuels vary greatly, depending on the source crop and location

In aggregate, biofuels currently replace around 5% of global petrol-type transport fuels and 1.5% of diesel fuels (by energy output), so the 'replacement' benefits over fossil fuels are currently limited. The FAO expects these shares to rise to 7.6% of petrol and 2.6% of diesel transport fuels by 2017 (see below), so the environmental benefits of replacing fossil fuels will still be small, especially given the increases in total transport fuel consumption projected for this period.

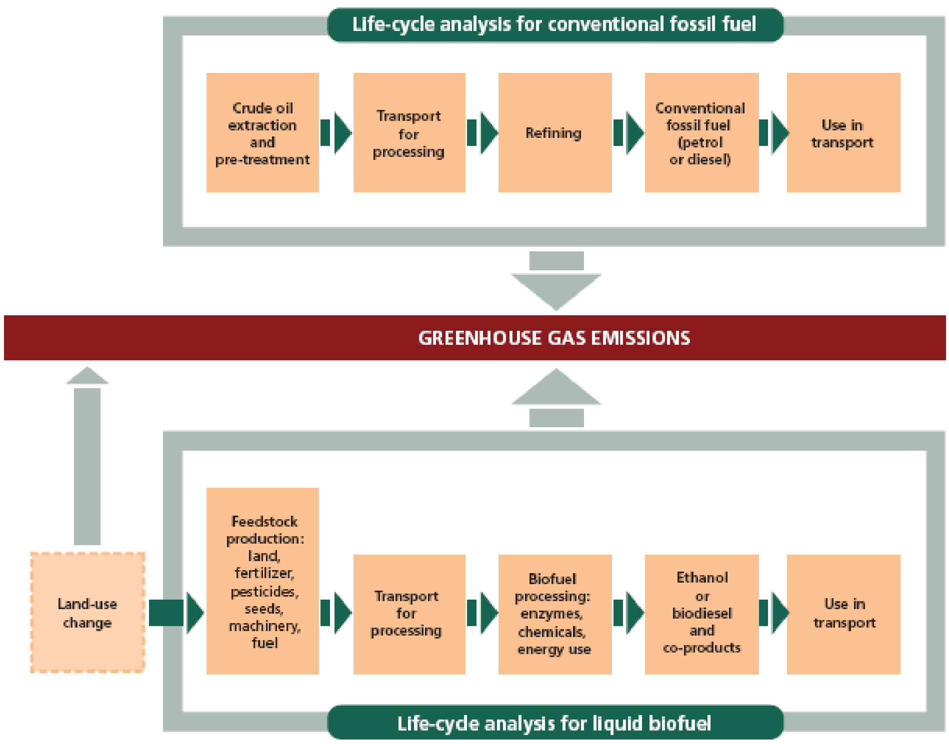
Biofuels can reduce GHG emissions by up to 90%, compared with their petroleum equivalents

Looking firstly at the GHG emissions of biofuels compared with petroleum, many older studies were ambiguous on the effectiveness of biofuel in reducing greenhouse gas emissions from vehicles that run on them, which is the main way in which biofuels are expected to reduce emissions. More recent research indicates that biofuels *do* emit lower emissions from vehicles that run on them, but not by as much as might be thought.

This is not the whole story however, and a comprehensive 'life-cycle' analysis is required to determine the net greenhouse gas emissions of biofuels relative to petroleum. Such analysis takes into account all greenhouse gas emissions and sequestrations associated with biofuel production and consumption, from crop to last drop, including land use change, crop growth, pesticides, fertilisers, production energy, transport and final consumption (see figure 12).

Life-cycle analysis has so far concentrated on the established biofuel sources of grains, oilseeds and sugar cane. These show that 'first generation' biofuels reduce emissions by between 25% (US corn) to 85% (Brazilian sugar cane) from their petroleum equivalents, but only if the most efficient production is used and if there are no emissions from land-use change (i.e. from clearing grasslands or forests). Asian palm oil production varies from a 50 to 80% reduction. 'Second generation' biofuels (see discussion below) are better still, with 70 to 90% reductions in emissions from fossil fuels, excluding land use change.[10]

Figure 12: Life-cycle analysis of GHG emissions from biofuels and petroleum



Source: FAO 2008, p. 56

[10] IEA 2006 and FAO 2008

Globally, if GHG emissions from associated land clearing are included, then biofuels have *increased* GHG emissions relative to the petroleum they replaced

Including land-use change in this analysis changes the results significantly. One recent study (Fargione 2008) asserted that clearing rainforests, savannahs and grasslands in Brazil, Indonesia, Malaysia and the US (where Conservation Reserves have been used for biofuel maize crops) to make way for biofuel crops has released 17 times the GHGs that were saved annually by replacing fossil fuels. If indirect land clearing could be included (e.g. to make way for other crops displaced by biofuels) then this GHG calculation would be even higher.

Another study (Righelato and Spracklen 2007) concluded that if all the land devoted to producing biofuels were instead planted with suitable trees then far more GHGs would be sequestered by the trees than is being saved by the biofuels. So if GHG reduction is the objective, then forestry is more effective than biofuels. Alternatively, straightforward energy consumption reduction in developed countries would be even cheaper, if GHG reductions are the only goal.

If land clearing is to be minimised, then biofuel crop intensity and yield will need to increase.

Increased intensity creates other potential problems for the local environment.

The second environmental concern raised in relation to biofuels has been the local environmental effects on biodiversity and rural communities. If land use change is to be minimised, then crop intensity and yields will need to increase instead. Greater crop yields on a given land area usually require greater water, fertiliser and other inputs. Problems associated with intensive agriculture more generally will arise for intensive biofuels production also, including water, soil and nutrient depletion and the loss of local natural and agricultural biodiversity.

The FAO and others have noted that many current biofuel crops are relatively water-hungry, which is why they are best suited to high rainfall tropical areas. Biofuel processing also requires water, for washing, distilling and evaporative cooling. Around 70% of current biofuel crops are thought to be rainfed, but future expansion is likely to include a greater share coming from irrigated areas, which will place greater pressure on local water supplies. Run-off from nitrogen fertilisers commonly used on grains and oilseeds can also create local hazards. With regard to the effects for local farming communities, the rise of biofuels has been a mixed blessing, particularly in developing countries. Biofuels have provided a new source of income, but have also contributed to rising food prices. Best practice in crop production — and more importantly, minimal land clearing — are clearly essential to minimising the adverse environmental effects of commercial ‘first generation’ biofuel production.

Outlook for biofuel technologies

Biofuel technologies are moving rapidly into a ‘second generation’ of commercial production. Some of these new methods build upon and improve the processing of ‘first generation’ biofuels, while others will replace them completely. And waiting behind them, are a ‘third generation’ of bio-energy production, which are still at a very experimental level of development. The FAO notes that not all biofuel methods that are technologically feasible will necessarily become economically feasible or environmentally desirable. For the reasons discussed above, it is to be hoped that the next generation of biofuel production will be less reliant on broadacre source crops and have lower environmental impacts.

The more promising ‘second generation’ biofuel technologies are:

New yeast strains that can ferment starch and cellulosic materials directly into ethanol, so that these sources do not have to be first converted into sugars (hydrolysis) and then fermented, as is currently the case for biofuels produced from all grains and starches (i.e. all sources except sugars). This biotechnology breakthrough would decrease the cost of making biofuels from starches and woody materials and broaden the range of suitable, cheap biofuel sources.

Cellulosic biomass (all grasses and woody plant materials) that can be broken down into sugars and then fermented into ethanol. Sources can include most soft woods (from purpose grown trees to forest floor waste), agricultural waste (straw, leaves, stalks, nut shells, sawdust, sugar cane bagasse) and even woody household and municipal waste. Woody and waste biomass is abundant and cheap, but the production technology is still too expensive for commercial production. Pilot projects and demonstration plants are under way.

Commercialisation of this technology appears to be at least five years away. It holds great promise for commercial-scale ethanol made from waste materials or from low-impact forestry or grasses planted on marginal and degraded lands.

Jatropha is a drought-tolerant small tree that can grow on marginal or degraded land with moderate rainfall, native to central America. Jatropha kernels contain 30% oil by weight. The oil is similar to castor oil but is not edible. It is already used to make soap, candles and cosmetics. Jatropha is cultivated in the Americas, Africa and parts of Asia. Biofuel is already being produced from jatropha seeds in India and elsewhere. It is more suited to dry areas than other oilseed crops due to its low water and nutrient needs, but it is not yet domesticated to a reliable performance and yield standard.

Microalgae (microscopic plants) with an oil content of up to 60%, grown in saline ponds or even sea water, with potential for conversion to biodiesel. Some types of oily seaweed and sea algae may also be possible sources of biodiesel. These sources are at an early research and investigation stage only.[11]

Other 'green fuel' developments involve converting naturally occurring gasses from landfill sites, piggeries and other sources into liquefied natural gas (LNG) that can then be used as a transport fuel. These methods do not produce ethanol or biodiesel and are not direct replacements for petrol or diesel, although they can of course, be used to run specially modified LNG vehicles.

Outlook for biofuel markets

The OECD expects global biofuel consumption for road transport to increase nearly tenfold by 2030.

This would require 3.5% of currently available arable land to be producing biofuels.

Based on current technologies and production costs, the OECD, FAO and IEA expect global biofuel consumption to double between 2007 to 2017, and to increase almost tenfold from 2004 levels by 2030. The share of biofuels in global fuel consumption will rise from 1% to 7%. The OECD and IEA expect "the biggest increases in biofuels consumption to occur in the US, Europe, developing Asia and in Brazil" — that is, in the countries where biofuels use is already well-established — and to be predominantly ethanol rather than biodiesel in form.

Looking at production and demand trends across less established locations, the larger Asian economies of China and India have planned to expand their biofuels supplies largely for the domestic market. China has ambitious targets for both production and consumption, at 15% of transport fuel consumption by 2020. Nine provinces already sell E10 through retail petrol stations and consumption is expanding fast. The government is working towards rolling it out across more provinces. In India, sugar cane ethanol production is expanding and E10 is being progressively made available nationally.

Other Asian producers, such as Malaysia and Indonesia, are positioning to build up their biofuels exports, particularly to the EU. Demand for biofuels from Europe will continue to be strong, given the EU's ambitious consumption targets. By 2005, Malaysia was already producing just under 15MT of palm oil from 4 million hectares of land. This is forecast to rise to 17 MT by 2010 and 18.5 MT by 2020, primarily through increased yield rather than increased land use.

In Indonesia, the National Biofuel Development Committee has proposed that biofuels be mandated at 2 to 2.5% of total fuel consumption, but the timing for the introduction of this target is undecided. Indonesian biofuel consumption is expected to reach 5ML of ethanol and 2,169 ML of biodiesel by 2017. Additional production will be for export. To accommodate this expansion, Indonesia plans to open up to 500,000 ha of new palm oil plantations each year.

If these forecasts are to be borne out, then the OECD and IEA estimate that the proportion of currently available arable land devoted to biofuel production worldwide will need to rise from an estimated 1% (14 million hectares) in 2004 to 3.5% (49 million hectares) by 2030 and crop yields will need to improve.[12]

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[11] Rural Industries Research and Development Corporation 2008, "Forum to study algae's potential for biofuels", Australian Government Media Release, 26 March.

[12] OECD-IEA 2007, *Renewables in Global Energy Supply*.

But as noted above, these forecasts for biofuel-related land use and crop yield increases are likely to bring global and local environmental costs, which, depending on how their expansion is managed, may or may not outweigh the net benefits of the biofuels being produced.

Figure 13: Global demand projections for biofuels

Country	fuel ethanol		biodiesel	
	2017 ML	average growth p.a. 2008-17, %	2017 ML	average growth p.a. 2008-17, %
Brazil	30,289	6.1	2,603	15.2
Canada	2,757	6.3	664	12.4
US	55,827	3.9	1,638	1.7
EU	11,962	9.6	14,843	5.6
Australia	1,004	12.5	994	0.9
South Africa	367	32.9	na	na
China	6,211	10.7	na	na
India	1,059	10.9	388	2.2
Indonesia	5	1.3	2,169	32.3
Malaysia	7	5.5	143	13.1
Thailand	1,374	19.8	na	na
World	**111,467**	**5.6**	**23,836**	**6.9**

Source: OECD-FAO 2008.

Biofuel and petroleum standard measures

B5	diesel blended with 5% biodiesel product
B10	diesel blended with 10% biodiesel product
E5	petrol (gasoline) blended with 5% ethanol
E10	petrol (gasoline) blended with 10% ethanol
E85	petrol (gasoline) blended with 85% ethanol
L	litres
ML	million litres
Mtoe	million tonnes of petroleum oil equivalent
Ttoe	thousand tonnes of petroleum oil equivalent

1 standard barrel of oil = 42 US gallons = 158 litres (approx.)

1 gallon = 4.54609 litres

1 litre = 0.21997 gallons

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