Bioethanol -
A Green*ergy* perspective

Summary

Green*ergy* is a significant producer and supplier of petroleum and biofuels into the UK transport fuels market, supplying over 15% of the UK's overall petrol and diesel market and approximately a third of the biofuels market. The company has extensive worldwide sourcing experience, with manufacturing operations in the UK and a blending facility in Rotterdam from which we supply customers across Europe. Green*ergy* is also a supplier of high percentage biofuel blends, the fastest growth area within the biofuels market, in particular B50 for commercial usage and E95 for buses.

In this Perspective, Green*ergy* presents the following:

- Bioethanol is made from a number of feedstocks, current production is from crops such as sugarcane, sugar beet and corn. In the future production is expected to be from a wider range of feedstocks including more fibrous grassy and woody material and a wider range of waste materials.

- Historically Brazil has been the largest producer of bioethanol. Production in the US is now slightly greater, but Brazil remains the principal world exporter.

- Bioethanol produced in Brazil from sugar cane gives significantly better carbon savings than bioethanol produced using crops grown in cooler climates.

- The overwheling majority of Brazilian sugarcane production is not carried out in the Amazon region. The development of new areas for sugarcane production is subject to strict environmental and sustainability criteria set by the Brazilian government.

- The expected growth in production must be managed for all uses through the establishment of a credible certification scheme as well as national land use planning and its enforcement.

1 What is bioethanol and how is it made

Perspective
Bioethanol (ethyl alcohol) is an alcohol made from renewable sources. It is normally produced by fermenting starchy or sugary solids from crops into bioethanol and water. This is often referred to as “first generation” bioethanol production. In the future it is hoped that “second generation” bioethanol production methods will become commercially viable.

Second generation methods allow a broader range of feedstocks, such as grassy fibrous materials to be converted into bioethanol either by the hydrolysis of cellulose and subsequent fermentation of free sugars; or by the gasification of biomass into carbon monoxide and hydrogen and then subsequent conversion to ethanol.

The following feedstocks can be used for bioethanol production:

Table 1: Bioethanol feedstocks

First generation biofuels		Second generation biofuels
Starchy products	**Sugary products**	
• Corn • Wheat • Tapioca • Waste products such as potato waste, bread waste	• Sugar cane • Sugar beet • Saw gum	• Wood • Straw • Waste paper • Grasses

2 Bioethanol in fuel

Perspective
Bioethanol is used both as a blend component of petrol and as stand-alone fuel. Most typical in Europe are 5% blends. Higher percentage blends can also be used with specific engine types.

In mainstream fuels, the amount of bioethanol that can be used is restricted by the European petrol standard, BS EN 228, which permits a maximum of 5% bioethanol in petrol. The European standards bodies are currently discussing increasing this amount, potentially to 10%.

Bioethanol, itself an oxygenate with an octane rating of 135, can be used to increase the power output of petrol as well as help reduce its carbon emissions.

A number of so-called “Flex-Fuel” vehicles produced by Ford, GM, Mazda and Saab are designed to be able to run on E85 (85% ethanol; 15% petrol).

3 Worldwide bioethanol production

Perspective
Global production of bioethanol is around 60[1] billion litres per year. The largest producer is the USA, which produces 49% of the world's bioethanol. Brazil is the second largest producer, but has a significant competitive cost advantage.

The world's largest producer of bioethanol is the US, where bioethanol is produced from corn. Growth of bioethanol production in the US has increased recently due to the banning of MTBE in petrol and concerns over supply security. In California, for example, gasoline must contain 5.7% ethanol. Very little US bioethanol is exported. Other significant ethanol producing countries include China, India and the EU.

All of Brazil's bioethanol is produced from sugar cane, most is used domestically approximately 22% is exported to the US, EU and other markets[2]. It is widely used in Brazil both because of the long history of Brazilian bioethanol production and because Flex-Fuel vehicles are widely available, they are designed to use blends from E23 to E100. By the end of 2006, 89% of light vehicles sold in Brazil were Flex-Fuel vehicles[3].

Table 2: Top 3 Bioethanol Producers

Billion Litres				
Country	**2004**	**2005**	**2006**	**2007**
USA	13	16	18	24
Brazil	15	16	17	19
China	4	4	4	2

Data from Renewable Fuels Association (www.ethanolrfa.org)

1 F.O.Licht's World Ethanol and Biofuels Report January 2009
2 www.unica.com.br/dadosCotacao/estatistica
3 www.unica.com.br/dadosCotacao/estatistica

The UK is not yet a significant bioethanol producer. British Sugar operate a sugar beet to ethanol plant in the East of England which produces 55,000 tonnes per year, but there are no other plants in operation. However, a joint venture between BP, Associated British Foods and DuPont to build a bioethanol plant at Saltend, Hull is due to begin in 2009 and locally sourced wheat will be the primary feedstock[4]. A further eight wheat to bioethanol plants are planned for construction in the UK over the next few years[5].

Bioethanol production costs vary widely with Brazilian production having a significant competitive advantage on a production cost basis alone.

Table 3: Bioethanol production costs

Feedstock and Country of Production	Cost per Litre of Ethanol (£/litre)
EU Sugar beet	0.26
EU Cereals	0.22
Canadian Corn	0.16
USA Corn	0.15
Brazil Sugar Cane	0.11

Source: Adapted from Jank M.S. seminar presentation: Potential Supply and Demand for Biofuels in the Coming Decade: Toward a US-Brazil Partnership. Feb 2007.

4 http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7034350
5 National Non-Food Crops Centre http://www.nnfcc.co.uk/metadot/index.pl?id=5680;isa=DBRow;op=show;dbview_id=2457

4 Carbon emissions from bioethanol

Perspective
The carbon saving from bioethanol varies greatly, depending on the type of feedstock used and where and how it is grown and the manner in which the bioethanol is processed. The improvement in carbon emissions relative to normal petrol can be anything from 0% to around 100%.

The carbon savings of bioethanol depend principally on three factors:

(i) The amount of fertiliser and other energy inputs used to grow the feedstock crop.

In general, crops grown in tropical countries give higher yields and require lower fertiliser input than crops produced in cooler regions – see Greenergy's Carbon Perspective for more information.

(ii) The efficiency of the bioethanol production process and the fuel used for processing.

Modern bioethanol production facilities, such as those in much of the Brazilian ethanol sector, are highly efficient and use sugar cane bagasse and residues to run the plant. They may even export electricity to the grid. However, many US corn-ethanol plants are powered by coal and are much less efficient.

(ii) The sugar content of the crops grown.

The higher the sugar content of the crop, the greater the efficiency of conversion of biomass to ethanol. While sugars can be converted directly to ethanol via yeast fermentation, starches must first be broken-down into sugars using enzymes such as amylase. Preparation of cellulosic material generally requires additional chemical and or enzymatic treatment.

5 Carbon benefits of Brazilian bioethanol

Perspective

Bioethanol produced in Brazil from sugar cane gives significantly better carbon savings than bioethanol produced using crops grown in cooler climates. When produced from sustainable sources bioethanol from Brazil can save over 5 times as much CO2 per litre of ethanol as bioethanol made from US corn and nearly three times as much as that made from wheat.

There are a number of reasons:

(i) Sugar cane production requires relatively low levels of fertiliser input per unit of output and cane is harvested efficiently in large plantations.

Table 4: Bioethanol crop productivity and inputs

	Sugar Cane	Sugar Beet	Corn
Litres ethanol / ha	5500	5000	3000
Kg N fertiliser / ha	64	101	164

Source: RTFO expert group (2007)

(ii) In Brazil the stalks of the sugar cane are generally burnt to generate the electricity to run the bioethanol production plant. In some cases, more excess electricity may be generated in this way than is required to run the bioethanol plant, so that electricity is fed back into the grid.

Overall, CO2 savings from bioethanol made from sugar cane in Brazil can be 59% compared with savings from bioethanol made from wheat in the UK and 77% more than US corn derived bioethanol[6].

6 RTFO Default factors, Carbon savings assume that land use change has not occurred.
http://www.renewablefuelsagency.org/_db/_documents/RFA_C&S_Technical_Guidance_Part_2_v1_200809194658.pdf

6 Impact of pre-harvest sugar cane burning

Perspective
Sugar cane harvesting has traditionally involved burning the cane to prepare it for manual harvesting. In Brazil, legislation has been introduced to address the environmental and social impacts of burning.

In South American sugar cane plantations it is common practice to burn the sugar cane prior to harvest to remove leaves and make it easier to cut and handle. Productivity of manual harvesting decreases if the cane is not burnt first.

Labour Unions are opposed to manual harvesting of un-burnt sugar cane because the harvest capacity of workers decreases by up to 80%, and workers are usually paid in tonnes cut per day[7]. Manual harvesting of un-burned sugar cane can mean an increased risk of injury to hands and fingers, attacks from insects and injury of eyes, face and arms from the microscopic prickles found on the edges of green sugar cane leaves[8].

However, there are concerns over the potential of sugar cane burning to create local air pollution and in particular:

- an increase in acidity in precipitation in sugar cane areas; and
- an increase in the level of aerosol particles during the burning season, with a subsequent risk of respiratory illnesses in the local community.

The federal government of Brazil has set a standard limit for air pollution[9]. In San Paolo (the largest sugar cane producing state in Brazil) a transition period for a reduction in pre-harvest burning has been established (ending in 2031)[10], as well as an additional law which shifts practices over to mechanised harvesting[11].

7 Ripoli et al. Energy potential of sugar cane biomass in Brazil Scientia Agricola vol. 57 n.4 Piracicaba Oct/Dec 2000
8 Ripoli et al. Energy potential of sugar cane biomass in Brazil Scientia Agricola vol. 57 n.4 Piracicaba Oct/Dec 2000
9 L.B.L.S. Lara et al. Chemical composition of rainwater and anthropogenic influences in the Piracicaba river Basin, Southeast Brazil Atmospheric Environment 35 (2001) 4937-4945
10 Law No. 11241, September 19th 2002
11 Law No. 10547, March 5th 2000

7 Bioethanol and deforestation

Perspective
In 2008 90% of bioethanol production in Brazil came from sugar cane grown in the centre-south of the country, some distance away from the Amazon region in the North West[12]. Sao Paolo state produces 60%. Other sugar cane producing states include Mato Grosso do Sol, Minas Gerais, Espirito Santo and Goiàs.

Only a small proportion of Brazilian bioethanol production takes place in the Amazon region because the equatorial climate of the Amazon region is unsuited to sugar cane production. Any expansion of sugar cane production in Brazil will be concentrated to Sao Paulo state because of the favourable soil conditions and more favourable humidity[13].

Brazilian environmental legislation requires a legal reserve (forestry cover on native trees or reforested with native trees) of 80% in the Amazon region, 35% in the Cerrado and 20% for the rest of the country[14].

Table 5: Causes of deforestation in the Amazon

Cattle ranches	60 - 70%
Small-scale, subsistence agriculture	30 - 40%
Logging, legal and illegal	2 - 4%
Fires, mining, urbanisation, road construction, dams	2 - 4%
Large-scale, commercial agriculture	1 - 2%
Selective logging and fires that burn under the forest canopy commonly result in forest degradation, not deforestation. Therefore these factor less in overall deforestation figures.	

Source: Rhett A Butler 'Deforestation in the Amazon'[15]

12 UNICA www.unica.com.br/dadosCotacao/estatistica
13 Goldemberg J. "The Sustainability of Ethanol production from Sugarcane", February 2008 www.unica.com.br
14 Goldemberg J. "The Sustainability of Ethanol production from Sugarcane", February 2008 www.unica.com.br
15 http://www.mongabay.com/brazil.html

Outside the Amazon rainforest, there are other ecologically sensitive areas such as “cerrado” vegetation and “pantanal” grasslands and “Atlantic Forests” that have been converted to agriculture including sugar cane production over the past 30 years. However, there are also opportunities to minimize any further negative impacts of sugar cane expansion by focusing growth in areas of abandoned ranch land and there is a commitment to improving the sustainability of production in other areas[16].

Brazil: Main Sugar Cane Regions

Source: Adapted from Jank M.S. seminar presentation: Potential Supply and Demand for Biofuels in the Coming Decade: Toward a US-Brazil Partnership. Feb 2007.

16 “Lula raps Europe Campaign against Brazil biofuel”, Reuters 9/07/2007

8 Second generation bioethanol production

Perspective
Second generation bioethanol production holds the potential benefit of achieving better carbon savings per hectare of land than first generation and a wider range of lower cost feedstocks including straw, waste paper and waste wood.

These benefits will require substantially higher plant capital and operating costs, and until these technologies have been tried and tested there will be a significant level of technology risk.

First generation bioethanol is produced from the starches or sugars that are present in a relatively small part of the plant, e.g. the starchy seeds of wheat plants, the extracted sugary liquor of sugar beet or the corn seeds of maize. This is only a small part of the total crop biomass and it is also the most valuable part.

Second generation production methods that can convert ligno-cellulosic (woody) plant matter into ethanol would allow more biomass to be converted to ethanol, either by using the whole of conventional crop or faster growing crops such as switchgrass. The potential to use land more efficiently and lower input crops hold out the prospect of better (lower) carbon intensity from second generation biofuels.

The key technical problem is how to break down the resilient lingo-cellulosic carbon chains into molecules that can be converted to ethanol or other liquid fuels such as methanol or butanol.

There are two main approaches being developed, neither of which is yet commercially viable without significant public subsidy:

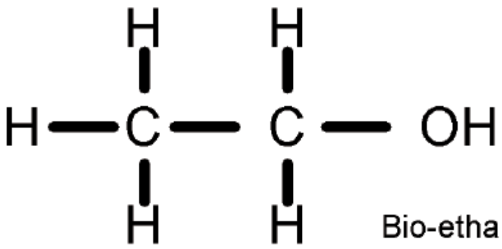
- Chemical conversion – using acids and/or enzymes to break down compounds into fermentable sugars.
- Thermal conversion of biomass into hydrogen and carbon monoxide and subsequent fermentation into ethanol using micro-organisms.

Second generation bioethanol holds the potential benefit of achieving better carbon savings per hectare of land than first generation and lower feedstock costs. However such benefits are likely to come at substantially higher plant capital and operating costs, with higher technology risk and therefore lower supply security due to the technology risk reliability considerations.

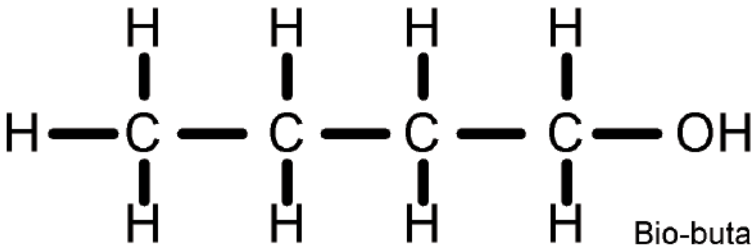
9 Comparing biobutanol and bioethanol

Perspective

The supporters of biobutanol claim that it is a better component than bioethanol for blending into petrol. However, the long term case for biobutanol depends on whether it can be produced more efficiently, both financially and with better whole of life carbon emissions, than bioethanol. These issues are currently unresolved.



Bio-ethanol



Bio-butanol

Bioethanol is the normal product of fermentation. It is found in beer, wine and is normally know as alcohol.

The alcohols are a group of chemicals that have the “OH” (oxygen and hydrogen) radical connected to a carbon atom. Thus methanol is the “C1” alcohol, ethanol is the “C2”, propanol is the “C3” and butanol is the “C4” alcohol.

The supporters of biobutanol claim that it is a better component for blending into petrol on two grounds:

1. It is has a “higher” energy content of 32 MJ/litre compared to 23.5 MJ/litre for bioethanol (petrol is typically 34.8MJ/litre).

However, this is potentially misleading for the following reasons:

- Cars internally adjust their fuelling rates to meet their driver’s horsepower and energy needs. For instance, the Saab Flex-Fuel car gives out 20% more power when running on bioethanol than petrol even though petrol has a higher energy density - it just uses more litres of bioethanol (but less energy joules which is more important from an environment and efficiency perspective).

- The supporters of biobutanol present their case in a way that suggests (but does not actually say) that this higher energy content is a result of achieving more energy from the feedstocks.

- Environmentally this may be misleading. A fundamental rule of science is that energy is conserved. This means that having a more “concentrated” energy in biobutanol can only be achieved by having (i) a dramatically more efficient production process, or (ii) lower yield per tonne of original feedstock or (iii) more energy inputs / more rejected low grade energy within the manufacturing process (likely). We do not know which of the above explanations is the correct, as the supporters of biobutanol have not released a whole of life energy and carbon balance for the process that can be independently reviewed. Until a whole of life energy and carbon balance is known, the energy benefits of biobutenol cannot be determined.

2. It is has better blending volatility characteristics than bioethanol.

- This appears to be a valid claim in the short-term, as at low inclusion rates bioethanol is a tricky molecule to blend into petrol from an RVP perspective and biobutanol is believed to be easier to blend. Biobutanol also has a lower oxygen content which means more can be blended into petrol within existing fuel specifications, which limit the amount of oxygen that can be added to petrol.

- However, neither of these benefits have longer term validity as petrol specifications are changing to allow up to 10% bioethanol inclusion rate from the current 5% limit (bioethanol is easy to blend from an RVP perspective at 10%). This change will also involve an increase in the amount of oxygen allowed in petrol. Once this happens the relative blending benefits of biobutanol will be lost.

Overall the long term case for biobutanol depends on:

(a) Whether biobutenol can be produced more efficiently, both financially and with better whole of life carbon emissions than bioethanol. This information should be produced by biobutenol supporters.

(b) If the answer to (a) is no, are the short-term blending benefits worth having?