TI-UP: Bioethanol - A Brief Review

Introduction

Ethanol is a fuel which may be used as an alternative to petrol, or in a blend with petrol to reduce the amount of petroleum consumed. Bioethanol is Ethanol produced through processing biological matter, either waste products or crops grown specifically for the purpose of creating Ethanol.

Bioethanol can be produced from a variety of raw materials. These fall into three main categories. Materials containing large amounts of sucrose which can be fermented, such as sugar cane; Starchy materials such as corn containing polysaccharides which can be hydrolysed to obtain sugars suitable for fermentation; and lignocellulosic biomass, which contains a complex of several polysaccharides that can similarly be broken down into fermentable sugars (sources range from paper to wood). The use of lignocellulosic biomass is often termed "2nd generation". This technology is in the development stage and is not yet widely used.

The dominant feedstock for current global bioethanol production is Corn, which is 60-70% starch. The majority of Bioethanol production currently occurs in the Americas, notably in Brazil and the US. The EU also produces a significant amount of bioethanol.

Worldwide Ethanol production (billions of litres/year)

America	***Asia***	***Europe***	***Africa***	***Oceania***
22.3	5.7	4.6	0.5	0.2

Source: A Demirbas, Progress and Recent Trends in Biofuels (2007)

Current Energy Ratio Estimates

An important consideration for Bioethanol production is the energy ratio of production. That is, the ratio of energy consumed in producing the fuel by growing, harvesting, and processing the raw materials to the energy obtained in the form of Bioethanol. These ratios are difficult to calculate, as it is not clear what values to attribute to the various elements comprising the energy flows, and how to value the co-products of bioethanol generation. The figures presented in this summary are the best available estimates. Three major regions are considered – Brazil, the US, and the EU.

BRAZIL

Background

A program to expand biofuel usage in Brazil was started in response to the Middle East oil embargo of 1973, although there had been limited bioethanol use before then. At that time, Brazil was very dependant on foreign oil imports, and sought to reduce that exposure. Brazil's program has been extremely successful, and today all gasoline sold in Brazil contains at least 25% ethanol (Biofuelling Brazil – An overview of the Bioethanol success story in Brazil).

Process

Brazil's alcohol is produced from sugar cane, which is pressed and the juice fermented. The fibrous residue from the milling (known as bagasse) can be burnt to supply the energy for the rest of the processing, and indeed some bioethanol plants in Brazil sell energy back to the grid.

A best estimate of energy ratio in Brazilian bioethanol production is 1:8 to 1:9. One report suggests as low as 1:3.1, but is likely in error, due to an overestimate of gasoline usage in cultivating feedstock. The greatest estimate found was 1:10.2

THE USA

Background

Strong government support has recently boosted the US bioethanol industry. In January 2006, President George W. Bush announced that the US would focus on producing bioethanol and other biofuel resources to reduce America's heavy dependence on fossil fuels. Import taxes on Brazilian bioethanol are also used to support the US corn based bioethanol industry. There appears to be strong potential for growth in the US bioethanol industry if second generation bioethanol production techniques become more economical.

Process

Bioethanol in the US is produced primarily from corn. The starch in this corn is broken down to obtain glucose syrup, which is fermented to produce the ethanol. This process has a significantly lower energy ratio than the one to produce bioethanol from sugar cane.

A best estimate of energy ratio in US production is 1:1.34. Estimates vary from < 1:1.2, to 1:2.09. A theoretical maximum for first generation techniques, given best practice throughout the production process of 1:2.51 is given by one source.

THE EU

Background

Both production and consumption of bio-fuels varies across the EU countries. In 2005 Spain was the largest producer of Bioethanol, Sweden was second, and Germany was third. Between 2004 and 2005 Germany experienced a 500% growth in production. If 2^{nd} generation biofuel production becomes more viable, Sweden is likely to grow in importance as a producer as its large forests will allow large sustainable production of bioethanol through Lignocellulosic biomass. It has been reported that the cost of producing feedstock means that support would likely to be necessary for a significant UK bioethanol production industry to develop.

Process

As well as using a grain fed process similar to that used in the US, the EU also uses wheat as a significant source of (starchy) feedstock. Sugar beet can also be used as a sugar containing feedstock. Sweet Sorghum is cited as a promising biomass crop.

Depending on the feedstock used, estimates for EU bioethanol energy ratios range from 1:0.7 to 1:5.6. This higher estimate is for a process involving acid hydrolysis of straw to produce the fermentable sugars, the least efficient crop in terms of energy ratio appears to be sugar beet. A figure similar to the US one of 1:1.34 is not unreasonable for corn based production.

Other developments and considerations:

Drawbacks

Some major drawbacks which should be taken into account when considering bioethanol production appear to be:-

- the transport costs of bioethanol are higher than those of petroleum because of its lower energy density;
- supply of bioethanol may change with weather fluctuations; and
- a large amount of water is required in the production chain for bioethanol, which may limit the feasibility of bioethanol production in locations where water resources are scarce, or are expected to become scarce due to climate change.

Future Potential

Improvements to current generation techniques can be made in a number of ways. Chief among these are development of different strains of organisms for fermenting the sugars into ethanol, and better process integration potentially allowing for higher energy ratios to be achieved.

The use of second generation production techniques, utilising lignocellulosic biomass as a feedstock has good potential. Although production costs are higher than those for bioethanol from cane, beet, or corn, many lignocellulosic materials are by-products of agricultural activities, industrial residues, or domestic waste. This offers huge potential for production of fuel ethanol at a large scale. However, the disposal of by products left by varied lignocellulosic feedstocks is likely to be more expensive than those from currently used techniques, as the products will vary in nature depending on the mix of feedstock being used at a given time.

Suitability as fuel

Ethanol does not carry the same energy per gallon as petrol. Using ethanol as a fuel will reduce miles travelled per gallon, and require drivers to fill up more often. On the other hand, ethanol has higher octane levels than gasoline, allowing greater compression ratios in engines running ethanol or a gasoline/ethanol mixture. This allows internal combustion engines optimized for operation on alcohol fuels to be about 20 per cent more energy-efficient than when operated on gasoline. Engines designed specifically to run on ethanol can be up to 30 per cent more efficient.
http://energysavingnow.com/biomass/carsbiofuel.shtml

This may mean that current estimates of energy ratios are slightly low, as the energy is produced in a form which will be more efficiently utilised.

List of Efficiency Estimates and Calculations

Brazil

The energy efficiency of bioethanol produced from sugarcane as in Brazil has been estimated at

1:3.1 – 1:3.9
Oliveira, M. E. D., B. E. Vaughan and E. J. Rykiel: 2005, 'Ethanol as Fuel: Energy, Carbon Dioxide Balances, and Ecological Footprint', Bioscience 55 (7), 593-602.

(This figure is likely a significant underestimate due to using a very high figure for gasoline use in agriculture while producing the feedstock)

1:8
Biofuels for transport, Ralph E H Sims, Massey University, NZ
The Russian Biofuels Association www.biofuels.ru

Average 1:8.3, Best 1:10.2
Macedo, I. d. C., M. R. L. V. Leal and J. E. A. R. Da Silva: 2004, Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil.

1:9.2
Greenhouse gas emissions and energy balances in bio-ethanol production and utilization in Brazil (1996)
Biomass and Bioenergy, Volume 14, Number 1, 10 March 1998, pp.77-81

The USA

The energy efficiency of bioethanol produced from maize as in the US has been estimated at

<1:2
Biofuels for transport, Ralph E H Sims, Massey University, NZ

1:1.34
US dept for Energy "Most reliable Figure"

1:1.38 with industry best of 1:2.09 and potential maximum of 1:2.51
How Much Energy Does It Take to Make a Gallon of Ethanol?, David Lorenz and David Morris
August 1995, Institute for Local-Self Reliance (ILSR)

Note: It is not clear which of these figures includes the co-product of the corn-bioethanol process of animal feed as an energy gain in their calculation. One source suggests that a ratio of 1:1.1 becomes about 1:1.34 when these co-products are taken account of.

The EU

The energy efficiency of bioethanol produced from various crops in the EU has been estimated at

Grain 1:0.9 – 1:2.6
Straw 1:0.8 – 1:5.6
Beet 1:0.7 – 1:2.0
UK Department for Transport (two different unpublished reports)
http://www.dft.gov.uk/pgr/roads/environment/research/cqvcf/internationalresourcecostsof3833?page=11

Beet 1:0.66
Venendaal, R., Jorgensen, U., Foster, C.A. European Energy Crops: A Synthesis, Biomass and Bioenergy Vol 13, No 3, pp147-185 (1997)

No factors have been noted which change significantly the energy ratio of producing bioethanol from corn from those noted in the US section, above.

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The Russian Biofuels Association www.biofuels.ru

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