Petroleum industry steps up biofuels investment

Following a previous article last year, Profs Patrick Corbett,[1*] Paul Mitchell,[2] and Paul Hughes[3] provide an update on how the petroleum industry is playing a significant role in the biofuels sector, itself a topic of some scientific controversy in terms of its environmental role.

Increasing awareness in the petroleum industry of the sustainability agenda, and resulting reporting to the economic, environmental, and social bottom lines - the 'Triple Bottom Line' - is leading to company mission statements that reflect a broader energy business agenda. For example, Shell's principles are to respect and safeguard people, to engage and work with stakeholders, maximize benefits to the community, minimize impact on the environment, use resources efficiently, and maximize profitability. Total's principles are to integrate operations into the local community, minimize the environmental impact, enhance the value of hydrocarbon resources, develop new energy sources, and improve products and their use. From these aspirational statements, the drivers of efficiency and use of biofuels can be increasingly justified to shareholders as emerging company activities.

Biofuels

Biofuels such as biodiesel and bioethanol provide a ready, and potentially greener, replacement to fossil fuels, to fill any future supply gaps in the latter. Motor manufacturers are excited by the potential for reduction in the transport carbon footprint. 'Key environmental benefit of bioethanol is that, unlike petroleum, its consumption doesn't significantly raise atmospheric levels of CO_2. This is because the CO_2 release by burning the fuel is counterbalanced by that which is removed from the environment by photosynthesis when growing crops and trees for ethanol production' (Saab, 2007). Emissions data for the various biofuel mixtures with traditional petrol or diesel show significant CO_2 emissions reductions are possible (Fig. 1; Total, 2007). The degree to which the whole life-cycle CO_2 emissions are reduced will depend on the source of the biofuel.

Petroleum industry activity

The petroleum industry is leading the development of biofuels with Shell currently the world's leading supplier of transport biofuels and Total the world's leading supplier of rape seed biodiesel. An earlier review of renewables activity by the oil industry used webpage hits as a measure of relative activity in the sector by leading oil companies (Corbett et al., 2007). A similar perspective can be achieved for biofuels (Table 1) and this shows that the US and Brazilian companies are possibly more active than some of their European counterparts.

Shell

Shell believes that they are the world's largest distributor of transport biofuels (Shell, 2007) and have been distributing first generation fuels for over 30 years. In 2006, they sold 3.5 billion litres, mainly in the US and Brazil (avoiding 3.5 million tonnes of CO_2 production).

Shell claims that ethanol (10% blend) can reduce CO_2 well-to-wheels by around 3%. Bio-ester (5% blend) will reduce emissions by 2.5%. Second generation

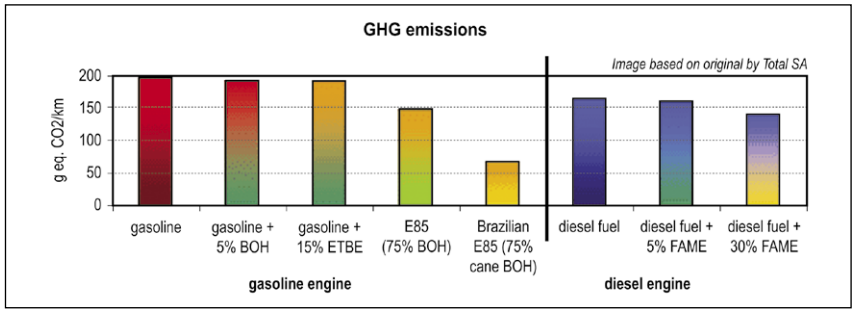

Figure 1 *Emissions reduction using biodiesel (from Total, 2007) (ETBE - ethyl-tertiary-butyl-ether; FAME – fatty acid methyl ester).*

Company	Renewables 2007	Biofuels 2007
Shell	1182	195
BP	200	31
Total	153	36
Chevron Texaco	72	70
ExxonMobil	30	73
Petrobras	14	35

Table 1 *Survey of 'renewables' and 'biofuels' hits on major oil companies websites using their own search engines. This suggests that for many companies biofuels is not yet seen as important as renewables for future company growth.*

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biofuels could potentially reduce well-to-wheels emissions by 90%, however, these will not be available in significant quantities for 5-10 years.

Shell has invested in a company - Iogen Coporation - which is making ethanol from straw using biological conversion. The product is called cellulose ethanol and in 2006, Shell, Volkswagen, and Iogen conducted a joint study in Germany to assess the economic feasibility of producing cellulose ethanol commercially. The study confirmed that cellulose ethanol has the potential for better CO_2 performance at prices competitive with standard petrol.

Shell has also invested in Choren Industries in Germany to create a biomass-to-liquids plant (Sundiesel) to come on stream in late 2007. A woody feedstock (wood chips) is gasified and then converted to synfuel (Biomass-to-liquids or BTL process identical to that used by the petroleum industry in gas-to-liquids or GTL). BTL can be blended with diesel. Used 100% it has the potential to reduce well-to-wheels emissions by 90%.

Figure 3 *Jatropha plant (left) and seeds (right) at the Biofuels Research Centre, University of Petroleum and Energy Studies, Dehradun, India.*

BP

In February 2007, BP announced a 10-year $500M research programme with University of California at Berkley, University of Illinois, and the Lawrence Berkley National Laboratory in California - known as the Energy Biosciences Institute (BP, 2007). BP supplies about 10% of the global biofuels market (2.7 billion litres ethanol blended with gasoline in 2006). Ethanol has two thirds of the energy of gasoline - requiring greater volumes. Biodiesel is roughly the same as diesel. BP states that a unit of corn-based ethanol requires 0.9 units of fossil energy for its production (fertiliser, transport, electricity, etc), so in effect you get 20 units of ethanol for one unit of fossil.

BP is working to develop second generation Biobutanol with DuPont - advantages are a higher energy content and less miscible in water - allowing for transport in existing pipeline. Biobutanol can be generated from the same crops as ethanol but by using a different bacterium (*Clostridium acetobutylicum*).

Total

Total has been producing biofuels for more than 10 years (Total, 2005, Fig. 2). There are two types:

- ETBE (ethyl-tertiary-butyl-ether) derived from iso-butylene produced in refining and ethanol from beet or cereal crops. EBTE is blended with gasoline up to 15%. ETBE produced in France, Germany, and Belgium (being considered in the UK).
- VME (vegetable-oil methyl esters), FAME (fatty acid Methyl Ester), or biodiesel, produced by reacting methanol with rape seed (canola) oil or sunflower oil. Total is the world's leading supplier of diesel containing rapeseed.

ETBE and VME are two or three times more expensive as gasoline or diesel to produce. Plants are only partly converted. Total also produces Aquazole - an emulsion of water and diesel, reduces NOx (30%) and particles (60%) - and LPG for diesels (di-Methyl-Ester from natural gas).

ExxonMobil

ExxonMobil's present perspective is that the scope for ethanol as an alternative fuel supply is limited. Biofuel on ExxonMobil's web pages is largely limited to reviews of energy supply rather than reflecting corporate activity in this arena.

Petrobras

Petrobras is getting ready to establish itself as the world leader in biofuels (Petrobras, 2007) by producing second generation plants by the turn of the decade (including converting sugar cane bagasse to cellulose ethanol, also BTL).

Biofuel development in the UK

A useful summary of UK biofuel activity can be found from Saab's website (Saab, 2007).

- First UK Bioethanol plant soon to become operational. In Somerset, operated by Green Sprint Fuels, the plant will be able to produce 105,000 tonnes of Bioethanol per year.
- Another plant in the northwest due to come on stream in 2008.
- Other plants in planning stages.
- First Harvest Bioethanol E85 (85% bioethanol/15% petrol) pumps opened in a Morrisons supermarket forecourt in 2006.
- Currently 14 E85 fuel pumps in the UK operated by Morrisons.
- Morrisons committed to operating one pump in every new store.
- Currently retailing for 2p/l less than petrol.
- UK is far behind Brazil and Sweden in terms of government support but nevertheless there are incentives:, e.g., annual 2% discount on car tax for bioethanol E85-ready cars, Vehicle Excise Duty discount of £20, and 20 p rebate on fuel duty to 2010.

Two vehicles in the UK are currently able to run on flex-fuels (unleaded, bioethanol and a mix). These are the SAAB 9-5 Biopower (17% more power on bioethanol but 20% less mileage)

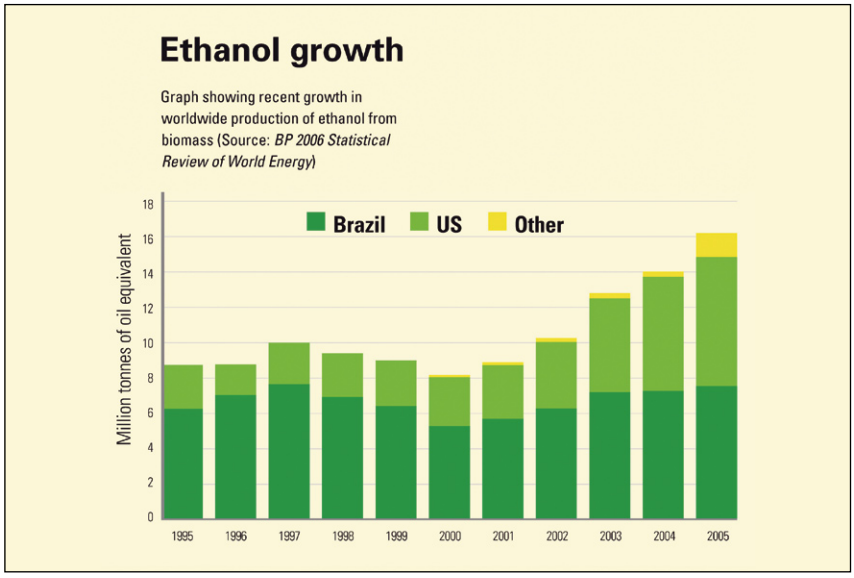

Figure 4 *Ethanol growth.*

and the Ford Focus FFV. The first Ford arrived in Somerset where the Somerset Biofuel project members - Somerset County Council, Wessex Grain, Avon and Somerset Police, and Wessex Water - intend to take 40 cars to use biofuel produced locally (Ford, 2007).

Types of Biofuels

First generation biofuels have been developed from food crops:

- Bioalcohol: Bioethanol or biobutanol made from the fermentation of starches or sugars (ETBE). Bioalcohol is blended with petrol and diesel (British Bioethanol, 2007). In the UK, bioethanol is sold by Tesco in the southeast of England. Ethanol is a highly corrosive liquid requiring deployment of special equipment.
- Bio-oils: Biodiesel are esters produced from oils such as rapeseed oil (RME, VME, FAME) or palm oil and typically added to diesel to produce biodiesel blends. In the UK, Biodiesel B30 is supplied by Harvest Energy (Harvest Energy, 2007).

There are various new initiatives to develop biofuels without competing with food supplies:

- Cellulose Ethanol. Using biomass residues - reed grass and poplar might be a better use of biofuels.
- Bio-Butanol. Generated from the same feedstock as bio-ethanol but having higher energy content and fitting into the fuel distribution system more easily as it is not as corrosive.
- Biomass-to-liquids (BTL). Non-food feedstock (e.g., wood chips) is first gasified and then a synthetic fuel (synfuel) is produced which can be blended with diesel.

Farming organisations (NFU) claim that second-generation biofuels (using waste products of wheat such as straw), jatropha (a non-edible crop grown on marginal land in east Africa and India, D1 Oils, 2007), household waste, and even sewage could produce enough to supply 77% of all new car sales in the UK.

Public concerns over the environmental benefit

'The current European Biofuels Directive is driving a huge expansion of biofuels exports from rainforest nations like Brazil, Indonesia, and Malaysia' (Boswell, 2006) is the kind of statement which generates negative press: 'Corn needs 30% more energy to produce than the finished fuel' 'Grain needed to fill a 4x4 with ethanol is sufficient to feed a person for a year' (*Independent*, 2007a). It is not the consumption of biofuels that causes concern - all positive - but the production of biofuels given the competition of agriculture for food production. A Dutch government study showed that sugar cane plantations in Brazil displace other food production into the tropical savannah. Friends of the Earth estimate that 87% of deforestation in Malaysia between 1985 and 2000 was to make way for palm oil plantations. The generation of biofuels using food crops is intended by many (Lord Oxburgh, D1 Oils, 2007) as a transition to second generation biofuels once the market is established.

There are also issues about contentious 'B99' subsidy. This allows US biodiesel to undercut European biodiesel. A loophole is also being practiced - European Biofuel is shipped to US mixed with gas ('splash and dash') and shipped back to Europe. The two trips across the Atlantic can't be positive for the environment (*Independent* 2007b).

The US and Brazil supply most of the world's ethanol from biomass (bioethanol, Fig. 4).

European Directive

European Directive (2003/30/EC) calls for a 5.75% increase in biofuels in the EU's fuel consumption by 2010. Perceived benefits of the Directive are to mitigate climate change and to favour to agricultural employment. Production of biodiesel in France and Italy is currently boosted by tax incentives (Frondel and Peters, 2007).

Bioethanol is currently the only commercial substitute for gasoline and RME (rape methyl ester) the only substitute for diesel. New crops (e.g., wheat, beet) have potential. Estimates suggest that some 14% of EU agricultural land will be needed for biofuel compliance production in 2010.

Energy balance

It is claimed that usage of biodiesel saves less than 100% of fossil fuel usage for three reasons (Frondel and Peters, 2007):

1. Heating value of biodiesel and conventional diesel are different (ca 10%).
2. Production requires agricultural machinery, fertilisers, pesticides.
3. Refinement of diesel requires less energy than conversion of rapeseed to biodiesel (16%).

With these considerations it is estimated that biodiesel is only 66% energy saving.

GHG emissions are 22-59% of fossil-diesel equivalent (savings from 41-78%).

Brazilian bioethanol is produced from sugar cane - European from sugar beet and wheat. Brazilian bioethanol production costs have recently dropped below petrol prices (Saab, 2007).

Electricity generation from combusting reed grass and poplar might be better. In the US, a study compared the production of ethanol from corn, switch grass, and wood biomass and biodiesel from soybean and sunflower plants (Pimentel, 2007). Corn requires 29% more fossil fuel energy, switch grass (45%), wood biomass (57%), soybean (27%), and sunflower (118%). 'Producing ethanol or biodiesel from plant biomass is going down the wrong road because you use more energy to produce these fuels than you get out of the combustion'. This study was disputed (van Gerpen, 2007) by taking the energy value of the soybean meal (reducing the difference to 2%). Other studies by the World Land Trust and the University of Leeds and reported in *The Guardian* (Guardian, 2007) also suggest that use of biofuels might lead to additional carbon emissions over those from fossil fuels because of the pressure to clear existing forest to make way for biofuel crops. Using waste biomass (straw, bagasse) is considered more acceptable and these biofuels are generally referred to as second generation.

Conclusions

- The petroleum industry is a significant player in the biofuels industry.
- Many petroleum companies are investing in broader energy sources that include biofuels.
- The international refining and supply operations of the major oil companies give them the opportunity to develop worldwide biofuels industry.
- First generation biofuels compete for land and crop use with food production. Second generation biofuels will need rapid development if biofuels are to replace petroleum in a sustainable way.

References

British Bioethanol [2007] www.britishbioethanol.co.uk.

BP [2007] *Frontiers*, April.

Cllr Boswell, Norwich Green Party [2006] *Independent* (11 December).

Corbett et al., [2007] Petroleum Industry and Renewables, *First Break*, **25**, 11-17.

Frondel, M. and Peters, J, [2007] Biodiesel a new Oildorado? *Energy Policy*, **35**, 1675-1684.

DI Oils [2007] www.d1plc.com/index.php.

ExxonMobil [2007] www.exxonmobil.com.

Ford [2007] www.carpages.co.uk/ford.

Van Gerpen, J. and Shrestha, D. [2007] Biodiesel Energy Balance, *Biodiesel Magazine*, October.

Guardian [2007] www.guardian.co.uk/environment/2007/aug/17/climatechange.energy.

Harvest Energy [2007] www.harvestenergy.co.uk.

Independent [2007a] 5 March.

Independent [2007b] 6 May.

Pimentel [2007] www.cornell.edu/stories/July05/ethanol.toocostly.ssl.html.

Saab [2007]www.saabbiopower.co.uk.

Shell [2007] www.shell.com.

Total [2005] *Energies*, **8**, July.

Total [2007] www.total.com.

Petrobras [2007] www.petrobras.com.br.

Errata

The following errors in* First Break *have been brought to our attention:

- In the article by Alireza Bashari entitled 'Integrated 3D seismic and petrophysical data of the Sarvak formation in the Persian Gulf' (*First Break*, November 2007, pp. 45-53), Figure 2 on p. 46 was incorrectly attributed to Balusseau, B., El-Demerdash, Mz, (1996), IHS Energy Group Information. We now understand that the original figure was designed by M.I. Al-Husseini and first published by Gulf PetroLink in 1997 (*GeoArabia*, 1997, **3**(3), 3, p. 438). We apologize for this inaccurate reference.
- In the article by Dan Bossie-Codreanu entitled 'The CO_2-EOR sequestration equation: recovery, dynamic monitoring, and co-optimization' (*First Break*, January 2008, pp. 73-83), the wrong illustration was used for Figure 14 on p. 81. The correct figure is published below. We are sorry about any confusion this may have caused.