Nuffield Farming Scholarships Trust

2006 Scholarship Report

BIO FUELS: THEIR IMPACT ON ARABLE FARMING AND THE OPPORTUNITIES CREATED

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1. Executive summary

1.1. Introduction

I left the world of corporate farming in March 2006 having spent 13 years managing arable farms for the Co-op, a career that I followed after my uncle succeeded the tenancy on the farm at home.

My application for a Nuffield Scholarship was driven by my desire to explore the future opportunities for arable farming and the alternatives to the perpetual search for ways to reduce costs and restructuring businesses. I wanted to understand the factors that would influence the future direction of the arable industry in the UK.

Taking stock, it was obvious that the most important factor to consider was the rapidly growing bio fuels industry and the use of land to produce feedstock material; vegetable oil, cereal grains, sugar beet and biomass and more importantly the opportunities it would present.

Farmers historically have had an inherent ability to overproduce. Would use of this surplus as feedstock for energy production be important in the future? I focused my research on bio fuels and their impact on arable farming and food production and the opportunities created.

1.2. Study aims and objectives

- Understanding the factors driving the bio fuels industry.
- An overview of the bio fuels industry, the existing and future or second generation technologies.
- To learn from countries with mature bio fuel industries.
- The impact that production of bio fuels will have on food production and land use in the UK.
- Should farmers produce crops for bio fuel production?
- The opportunities that bio fuels offer for farmers to become energy producers.
- To promote bio fuels and the associated opportunities.

I left a despondent industry in April 2006, when my first leg of travel took me to Germany, Austria, Sweden and Ukraine. Feed wheat was worth £68.5/tonne. The situation almost twelve months later when I departed to travel the US Corn Belt was quite different with a rising market and wheat worth £93/tonne. In between I had been back to Germany and Austria for work reasons.

1.3. Getting things into perspective

Worldwide every day, we devour the energy equivalent of about 200 million barrels of oil. Much of this energy comes from coal, gas and nuclear fuel. Energy demands are set to rise by 50% to 60% by 2030. If the worlds total 2006 cereal grains harvest of 1.57 billion tonnes was converted into ethanol, in energy equivalent this would satisfy our energy demands for only 11 days; a sobering thought! The costs incurred in growing crops leave bio fuels at an inherent disadvantage. Direct subsidy, tax breaks or incentives are necessary to make bio fuels a viable alternative. Despite the obvious drawbacks political drivers have mandated use and underpinned the market leading to the rapid development of the bio fuels industry.

1.4. What are the drivers for bio fuels?

Climate change - There is sufficient scientific evidence now to confirm the world is getting warmer and its climate changing. Earth surface temperatures have increasing by 0.5°C. Bio fuels can help in the reduction of greenhouse gas emissions. For Europe climate change and the resulting legislation to achieve reductions in greenhouse gas emissions underpins the market for bio fuels.

Energy security - Are we wise to expect uninterrupted supplies of energy from countries with unstable political regimes. In 2005, 85% of Europe's and 65% of US oil was imported. Russia and Iran between then have over 45% of the worlds proven gas reserves. Domestically produced bio fuels can reduce the reliance on imported energy.

Substitution of fossil fuels with bio fuels - The Association for the Study of Peak Oil estimate that oil production will drop from todays level of 82 million barrels per day to 36 million barrels per day by 2050. China's consumption is set to double to 14 million barrels per day by 2025. Fossil fuels will not run out but in the face of increasing demand and reduced supply prices will increase and alternatives are required.

1.5. The market for Bio fuels and the economics

In 2006 in the UK we used 20.14 million tonnes of diesel and 17.89 million tonnes of petrol. We have committed to achieving a target of 5% bio fuels use by 2010 and 2.9 million tonnes of rape and 2.28 million tonnes of wheat would be required if that bio fuel was made domestically. We have a guaranteed market for bio fuels and we can use our exportable surplus of cereal grains to produce the ethanol and bio diesel that we will require. It is recognised that bio fuels made from a range of different crops result in more energy being produced than was used in the production of the raw material and conversion to a fuel and the bio fuel can provide a reduction in greenhouse gas emissions. However, the increase in commodity prices that bio fuels have created will limit their production in some cases. For example, the cost of production of wheat ethanol is currently 34p/l and the ethanol is worth 23p/l. Sugar cane has physiological advantages over temperate environment crops and provides the most efficient route to producing ethanol, with costs of production as low as 12.5p/litre.

1.6. "Food versus fuel" - will bio fuels lead to starvation of the world's population

A Hummer H2 Sports Utility Vehicle requires one tonne of corn per 1350 miles the same amount of corn could feed 4 people for a whole year. The entire US corn crop converted into ethanol would only satisfy 21% of gasoline requirements. In April 2007 there were 122 operational ethanol plants in the US, with a further 82 under construction. With all these plants operational corn usage in ethanol production is set to reach 120 million tonnes by 2008; in 2006 the US produced 273 million tonnes of corn. Bio fuels and increasing demand for food will lead to an unprecedented demand for agricultural commodities.

The world will be faced with a serious challenge but through technological advance such as genetically modified crops, second generation technology and the use of new plants such as jatropha and algae to produce oil the demands will be met. Higher prices for agricultural commodities will increase the land area cropped globally and energy will be produced from organic waste and animal slurries.

1.7. Lessons to be learnt from successful bio fuel projects

In all the countries I visited there are a number of characteristics that defined successful projects; I define a successful project as one which is profitable and has a sustainable and secure future:

Collaboration and Cooperation - Collaboration and cooperation between farmers, local authorities, waste companies and other parties are key ingredients in a successful bio fuels plant.

Farmer equity - Investment in bio fuel facilities offer farmers the opportunity to take ownership of the next stage of a new supply chain, and in so doing take control of their own destiny. There is a vested interest for the plant to succeed by the party that supplies the raw materials.

Security and availability of feedstock - Having plentiful supplies of the feedstock material a bio fuel plant uses grown in close proximity is vital.

Using waste materials and by products for bio fuel production - Waste materials can be utilised and combined with energy crops to process waste and improve the profitability of biogas and biomass facilities. Slurry is used widely in Germany as a base material for biogas plants, with maize added to improve gas production.

Utilising the heat energy produced in electricity generation - The financial viability of power generation and the efficiency is improved dramatically if the heat energy produced can be utilised.

Government support - Subsidy, Tax breaks and Capital funding - Bio fuels are inherently disadvantaged against fossil fuels due to the cost of production of the raw materials to make them. To stimulate development support from capital grants, tax breaks or subsidy is required. Allowing primary producers to qualify for a higher capital grant rates encourages vertical integration and recognising local sustainability keeping profits generated in the production cycle.

The planning process and regulation - It is essential that projects proceed without major delay and difficulty with planning and obtaining the necessary statutory consents.

Promotion - Promotion of bio fuels and their benefits is essential to raise awareness.

1.8. Recommendations

To UK farmers

- Make the best of the increase in commodity prices as a result of first generation bio fuel production.
- Grow cereals and oilseeds for bio fuel production only if contract prices are in line with the market place.
- Invest in new energy supply chains, and become producers of energy from biogas supplying a local market for imbedded energy for new developments.
- Investigate the possibility of using straw to produce energy as technology develops.
- Consider producing fuel from rapeseed if concessionary fuel (red diesel) for agriculture disappears.

To UK Government

- Take a world lead on sustainable and ethical bio fuel policy.
- Make capital grant funding for second generation bio fuel technology available.
- Where cities are implementing congestion charging measures, make vehicles running on bio fuels exempt from the charges.
- Allow concessionary road tax on bio fuel cars. (E85 and Bio methane cars)
- Consolidate the capital grants available for investment in bio fuels infrastructure into one programme and make higher rates available for primary producers.

- Through road tax and company car tax concessions encourage the use of bio fuels in captive vehicle fleets, particularly in situations where emissions and pollution are worse, for example buses and vehicles in cities.
- Review the restrictions on biotechnology for crops used exclusively for energy production.
- Decentralised generation of electricity is vital in the future with utilisation of heat from CHP essential to improve efficiency and financial viability. Retrofitting district heating into existing housing is uneconomic, so new developments must be built with district heating incorporated.
- Encourage the use of renewable heat from CHP for residential and industrial use by extending the Renewables Obligation to cover heat, or raising tax on heating fuel.
- Put in place legislation and arrangements to allow bio methane to be exported into the Natural Gas Grid.
- Above all else avoid complexity and make all measures for encouraging bio fuels simple so as not to deter farmers and investors.

1.9. Conclusions

Are there opportunities for farmers?

The most genuine opportunity I believe that exists for farmers in the UK is biogas. Biogas offers farmers the opportunity to become independent energy producers, producing electricity from a combination of waste materials (vegetable and food waste), animal slurries and crops specifically grown for energy such as maize silage. Using slurry and waste materials reduces the feedstock costs and improves the profitability. There are plentiful sources of these wastes available. In April 2009 the review of the Renewables Obligation will take effect and Renewable Obligation Certificates's from biogas generation of electricity will be doubled in value. Moreover, in terms of energy production per hectare, growing energy crops such as maize and converting the crop into methane through anaerobic digestion is one of the most efficient uses of land for energy production. In the future, technology for upgrading gas will improve and opportunities to export gas into the gas grid; a higher value market than using gas to generate electricity will give potential for improved profitability.

What impacts will the production of bio fuels will have on food production and land use in the UK?

Much has unfolded in the last two years. There has been a massive increase in the price of all arable commodities and an associated improvement in arable farm profitability. The cost of food has responded to the increase in the price of agricultural commodities, with inflation on food running at 6%. Institutions and investors, such as Blackrock are looking to buy land and engage equity in practical farming. Schroders have set up an agricultural fund to trade in commodities and Agribusiness.

Land prices have risen and to give an indication of by how much; a 4500 acre Estate of grade 2 arable land that was sold in 2004 for £15.7 million has recently be sold for £32 million.!! Marian Fischer Boel has responded to the increased demand and price increase for agricultural commodities by removing compulsory set aside in the European Community to increase supply for 2008 and stem the reduction in stocks of cereal grains. Agriculture has become part of the solution to the problems we face as opposed to being part of the problem. Land values will reflect the fact that agricultural commodities, whether they be cereal grains, oilseeds or biomass, have a vital role to play in the production of energy as well as producing food.

Should farmers produce crops for bio fuel production? Yes and No

Yes – Where it is possible to keep control of the whole energy chain and be an independent supplier of energy, growing the raw material, utilising waste materials and supplying electricity into the grid and heat energy for developments.

No – Where the farmer is a commodity producer supplying bio fuel feedstock to produce bio ethanol and bio diesel at whatever price the buyer offers.

For the UK, domestic ethanol production will never compete with production from sugar cane in Brazil, with the physiological advantages of the crop and lower costs of production. In the UK we have 60.78 million consumers on our doorstep with more interest in provenance of food than ever before, we should exploit this market first and foremost.

Price improvements are the result of increased demand for agricultural products globally, bio fuels don't have to be produced at home we can just benefit from the price improvements.

Will the world's population starve?

No - There will be unprecedented demand for agricultural commodities, however the world's population will not starve and the increased demand will be met through technology:
GM technology advances will enable plants to convert energy into carbohydrate more efficiently in the future; we must embrace this technology. Second generation bio fuel technology will enable straw, corn stalks, rape meal and forest thinnings to be converted into bio fuels. Whilst second generation bio fuel technology develops Governments must implement sustainable and ethical bio fuels policies to encourage the industry to develop, but not distort the balance between food and energy production. Energy will be produced from organic waste and agricultural waste and slurries supplemented with energy crops.

On a personal level

The Nuffield experience has given me the stimulus and confidence to set up my own business. In January 2007 my company Greenerbridges Limited began trading. I now manage a number of farms for a Trust and also manage a farming business and property portfolio for a private landowner. The knowledge I have acquired through my Scholarship has enabled me to move into the area of bio fuels and I now work on a number of bio fuel projects, in particular for Biogen Limited helping develop a network of biogas plants across the UK.

2. Acknowledgements

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***Disclaimer:** This report is result of my studies and the opinions I have expressed are my own and not necessarily those of the Nuffield Farming Scholarships Trust or of my Sponsor.*

3. Aims and objectives

In explaining my aims and objectives I summarise the position I found myself in September 2006. My father was a tenant on a livestock farm in Breconshire, South Wales. After studying agriculture at the University of Reading my father passed away and my uncle succeeded the tenancy of the farm at home. As a result, in 1992 I started a career as a farm manager with CWS Agriculture and managed various farms around the country, mainly arable and vegetable and progressed up the management ladder. Through various changes in the business structure and name, in 2004 I became Head of Farming Operations for Farmcare, having been an Area Manager since 2001.

For a corporate farming business heavily involved in contract farming, dairy and vegetable production the changes in the business through a period of low commodity prices had been massive. I had instigated much restructuring and am not proud of the fact that in the previous five years I had been responsible for the redundancy of 35 staff.

I had developed a rather pessimistic view of the future for the arable sector and the business I worked for. What else could be done with cereal prices of £65/tonne, increasing costs and decreasing support payments apart from continually cutting costs? On a personal level after 13 years working for the Co-op it was time for a change. When I applied for a Nuffield Scholarship I was working out my notice period. I wanted to find out what the future direction for the arable sector was and if I saw myself as part of that sector where did I fit into that, and what opportunities there were for me and other arable farmers.

Visiting many farmers and large businesses in the spring of 2006, it became obvious that the most important factor I should consider was the bio fuels industry and the use of land to produce feedstock material; vegetable oil, cereal grains, sugar beet and biomass and more importantly the opportunities it would present. The Government has established bio fuel targets with the Renewable Obligation Order and Renewable Transport Fuel obligation so there was a guaranteed market for bio fuels.

I focused my research on bio fuels and their impact on arable farming and food production and the opportunities created.

Much has changed in the last two years and some of the effects of bio fuels have become obvious, however writing this report my aims have remained largely unchanged and I summarise these as:

- Understanding the factors driving the bio fuels industry.
- An overview of the bio fuels industry, the existing and future or second generation technologies.
- To learn from countries with mature bio fuel industries.
- The impact that production of bio fuels will have on food production and land use in the UK.
- Should farmers produce crops for bio fuel production?
- The opportunities that bio fuels offer for farmers to become energy producers.
- To promote bio fuels and the associated opportunities.

4. Introduction

In April 2006 there was much interest in bio fuels in the UK. I attended three conferences dedicated to the subject; however for bio fuels generally we were a country long on talk and reports with not a great deal of action. Road hauliers and some farmers were experimenting with the production of bio diesel from chip fat and cold pressed rape oil with small scale refineries, but Argent's plant in Motherwell producing bio diesel from used cooking oil and tallow was the only large scale operational plant producing bio fuels for road transport in the UK.

Green Spirit were seeking investors for a plant to produce ethanol from wheat at Henstridge in Somerset and British Sugar were about to start construction of a plant to produce butanol from sugar beet at Wissington. The position for biomass was more advanced with Short Rotation Coppice and Miscanthus being co fired in coal fired power stations, and willow was being used in small scale biomass boilers for heating.

Only three farm based biogas plants were operational; at Turiff in Aberdeenshire, Bedfordia Farms Bedfordshire and Holsworthy in Devon.

Elsewhere the situation was very different with Germany leading the way in Europe, with 2.5 million tonnes of bio diesel produced in 2005 and many farm based biogas plants. Austria produced 11% of all energy from biomass in 2005, and Sweden had well developed activity in biomass, bio ethanol, and biogas. US production of ethanol topped 20 billion litres in 2006, with Brazil producing 16.5 billion litres. Bio fuels were creating a rapidly developing new market for agricultural commodities to be used as feed stocks in their production.

I felt bio fuels represented a clear development. Farmers have historically had an inherent ability to overproduce. UK farmers would now have the opportunity to produce commodities that the nation required for bio fuel production. The demise of North Sea oil has increased our reliance on imported energy, and the public has realised the implications of this. The value of locally produced renewable energy from bio fuels is recognised.

In an attempt to get a full understanding of bio fuels, and learn lessons from countries that were far further forward than we were in the UK, my first leg of travel took me to Germany, Austria and Sweden. I tended to look at road transport bio fuels or use of crops that we would consider part of a normal arable rotation, although I have looked at woody biomass for heat and power as there are some important lessons to be learnt. Having been in Russia in 2005, I thought it relevant to visit Ukraine to get a picture of a country with land not in production, that had the potential to become a serious producer of bio fuel feed stocks.

When I left in April 2006 feed wheat was trading at £68/tonne. Twelve months later when I flew to America to looking at ethanol production in the US Corn Belt the value had risen to £93/tonne. Just before the winter conference in November 2007 the price peaked at £165/tonne. The increase in commodity prices over the last two years has led to inflation on food running at 6%. I was fortunate to visit Germany, Austria and Poland through work in 2007, and also visited a bio ethanol plant in France on the Nuffield arable group visit in May 2007.

The debate on the use of land to produce food or fuel has become headline material, particularly in America, where at the time of writing this report the latest impact of the ethanol revolution is a large increase in the price of beer, and the closure of many small breweries due to farmers switching to growing corn for ethanol production instead of barley and hops traditionally grown in Washington State.

5. Bio fuel basics

Before going any further it is relevant to consider some basic background on bio fuels:

5.1 What are bio fuels?

Bio fuels are a group of fuels that are derived from biomass or combustible oils produced by plants. They are a renewable energy source; the carbon dioxide released when they are burnt was absorbed from the atmosphere during plant growth. Liquid bio fuels generally supply the road fuel market while solid bio fuels tend to supply the combined heat and power (CHP) market. Bio fuels are not a new technology. Rudolf Von Diesel exhibited an engine at the Paris exhibition in 1900 that ran on peanut oil, and Henry Ford designed cars to run on ethanol.

Biomass is the total dry organic matter or stored energy content of living or recently living organisms. Biomass can be used for fuel directly by burning it, indirectly by fermentation to an alcohol, or extracting the combustible oils. Biomass also includes biodegradable wastes that can be burnt as fuel.

5.2 Road transport Bio Fuels

5.2.1 Bio ethanol

Bio ethanol C_2H_5OH can be produced by fermentation of sugar from sugar cane, sugar beet or starch from cereal grains**.** Bio ethanol is increasingly used as an oxygen additive in petrol. Inclusion levels can be increased to 10%, but beyond that level specially designed engines, as fitted to the Ford Focus and Saab E85 flex cars that can use 85% ethanol are required.

Production from wheat will dominate domestic production. Three tonnes of wheat are required to produce one tonne of ethanol.

There are currently plans for the construction of nine plants in the UK to produce 1.175 million tonnes. Only two are under construction. US production of ethanol topped 20 billion litres in 2006, with Brazil producing 16.5billion litres. Europe produced 3.4 billion litres; the UK none.

5.2.2 Bio butanol

Bio butanol is similar to ethanol in characteristics and the bio fuel produced from sugar beet by British Sugar at Wissington plant. Butanol has advantages in that it is less evaporative than ethanol and petrol and is more resistant to absorption of water, enabling it to be transferred in existing pipelines. It can also be used as a replacement for petrol up to 100%, unlike ethanol which can only be used as an additive up to 85% and then only after engine modification.

5.2.3 Bio diesel

Bio diesel is a substitute fuel for compression-ignition (diesel) internal combustion engines, produced by the transesterification of waste or vegetable oils and animal oils or fats to form methyl esters; rape methyl ester (RME), soya methyl ester (SME).

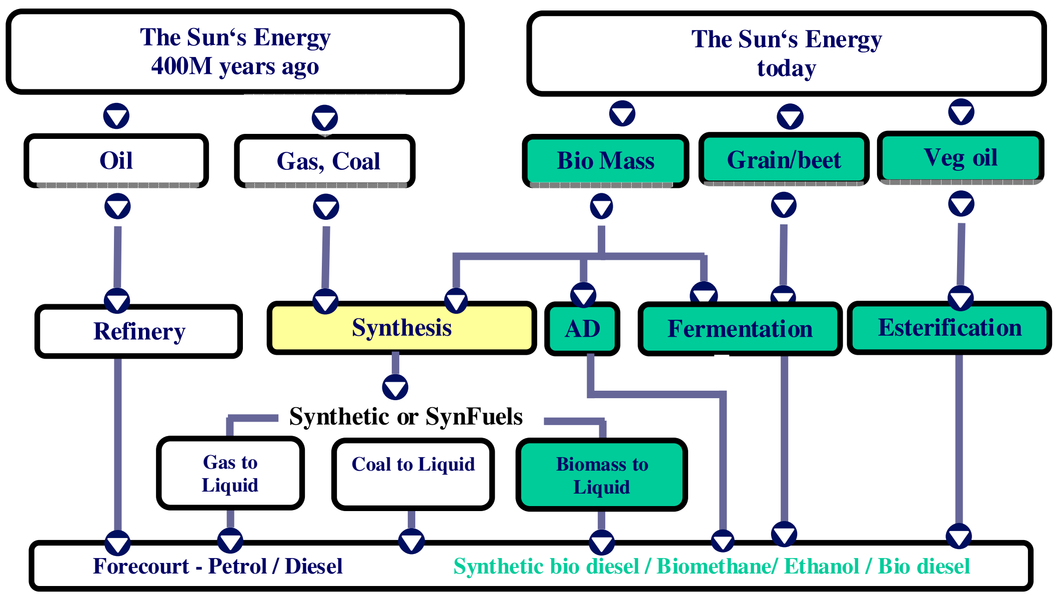
At 100% inclusion 5-6% more fuel is required to maintain the same level of power and performance in an engine as fossil fuel. EN14214 is the European standard for bio diesel. The standard limits the percentage of soya oil used in production to 20%. Fuel additives are necessary to prevent the waxing of bio diesel in lower temperatures.

To qualify for the 20p/l fuel duty in the UK Customs and revenue must have proof that the fuel has 96.5% ester content.

5.2.4 Biogas

The important component of biogas is Methane CH_4, which is produced from woody biomass by gasification or vegetative biomass and organic waste by anaerobic digestion (AD). Biogas which contains 50-70% methane can be cleaned to remove hydrogen sulphide and carbon dioxide and compressed and used as a vehicle fuel as Compressed Bio Gas or Compressed Bio methane. This carries a duty concession in the UK of 40 ppl, but unlike Sweden, Germany and Italy where it is used as a fuel, particularly in captive vehicle fleets, its use as a vehicle fuel is limited.

Routes to produce road transport bio fuels



5.2.5 Second generation bio fuels

Second Generation Bio fuels or conversion of Biomass into Liquid Fuel (Biomass to Liquid – BtL) is the terminology used to describe:-

a) Bio ethanol produced from cellulose, hemicellulose and ligno cellulose, (straw, wood, biomass crops, paper, grass etc) by enzyme breakdown, acid hydrolysis or thermophilic conversion of the cellulose after the lignin has been separated into sugars that are fermented to ethanol.

b) Synthetic bio diesel produced by gasification of cellulose, hemicellulose and ligno cellulose, (straw, wood, biomass crops) and conversion of the "syn gas" into bio diesel through the Fischer Tropsch process.

Second generation technology is in its infancy so production costs are high. Future bio fuel production will move towards second generation as too much land would be necessary to satisfy higher levels of bio fuel substitution for fossil fuels relative to food production. Companies developing the technology are Iogen, Abengoa, TMO and Choren industries. In early 2007 Abengoa will have a straw to bio ethanol plant running in Spain, and Choren Industries will have a wood chip to synthetic bio diesel plant running in Germany.

5.3 Bio fuels for heat and electricity

5.3.1 Bio fuels for electricity

Biomass for the energy market can be broken down as follow:-

- Dedicated energy crops.
  - Miscanthus and short rotation coppice.
  - Maize, grass, whole crop wheat grown and ensiled for energy.
- Agricultural crop residues.
- Forestry residues.
- Wood waste.
- Animal wastes and slurries.
- The organic fraction of municipal waste.

Biomass has a major advantage over wind and photovoltaic in that energy can be produced on demand. There are three routes for biomass to be converted into electricity.

5.3.2 Combustion

- Burning to produce heat and power through heating water to produce steam to drive a steam turbine.
- Co firing with coal.

5.3.3 Gasification – Biogas

- Biomass is heated, not burned, to very high temperatures, producing hydrogen, methane and carbon monoxide.
- The gases produced can be converted into synthetic bio fuels (see above), or used to fuel in a gas engine to generate electricity.

5.3.4 Anaerobic digestion – Biogas

- Biomass (usually animal slurries, food/vegetable waste organic waste) is digested anaerobically by mesophylic (at 38ºC) or thermophylic bacteria (at 55ºC) to produce methane which is used to fuel a gas engine to generate electricity and heat.

5.3.5 Straight vegetable oil and bio diesel

- Can be used as a replacement for fossil fuel diesel in a generator set.

With the generation of electricity the following levels of efficiency apply:-

Generation of electricity only	–	20-30% efficient
Biomass for heating	–	85-95% efficient
Generation of electricity and heat together *(Combined heat and power)*	-	75-90% efficient

In the UK we waste more heat energy from central generation of electricity than would be needed to satisfy the heat requirements of the country.

Combined heat and power offers an efficient use for biomass, particularly if a "year round" use of heat can be found. Medium scale CHP technology is more efficient than small scale CHP, so successful projects must be linked to significant heat usage such as a district heating network.

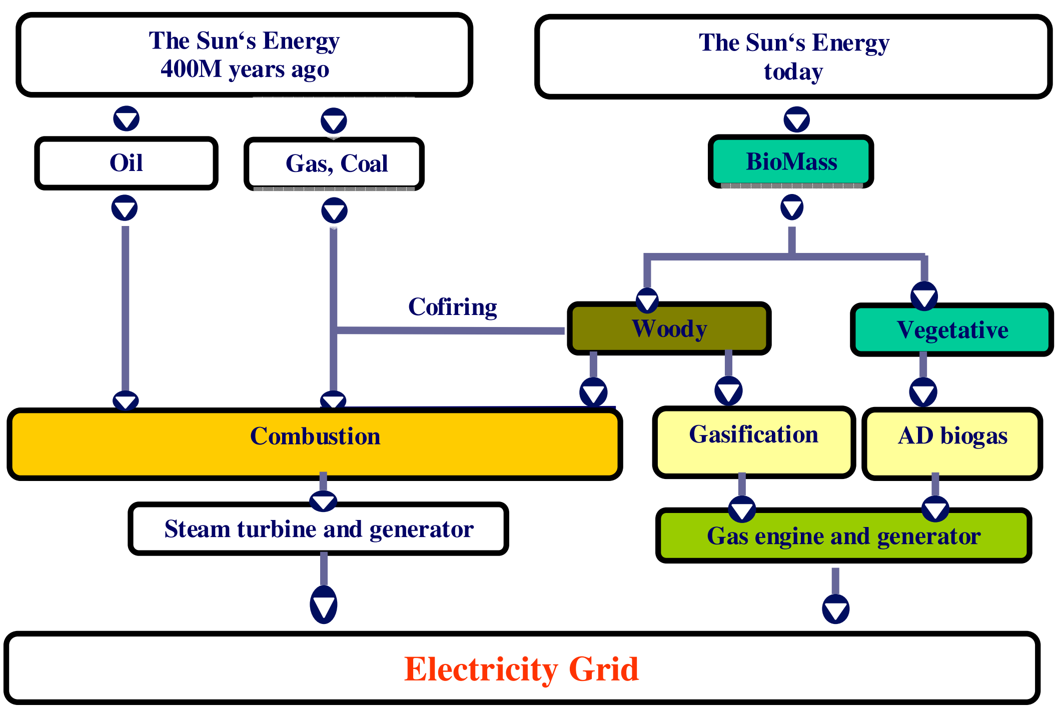
5.4 Heat from biomass

Heat only systems on a medium scale offer the most efficient and cost effective use of biomass.

Fuels for biomass heating systems include:-

- Wood chips.
- Wood pellets. (For confined areas, pellets can be blown into a gravity feed hopper)
- Miscanthus.
- Cereal grains. (Wheat, oats)
- Rape meal. (By-product after oil extraction)

Routes to produce electricity from fossil fuels and biomass



6. The Drivers for Bio fuels

There are a number of key drivers for bio fuel production and use:

6.1 Global warming and climate change

The Earth's average temperature rose by more than half a degree Celsius over the last century according to NASA. Despite Al Gore's Oscar wining performance in An Inconvenient Truth and the crusade to communicate the message that climate change is the largest threat to our civilisation, there is still not complete agreement among scientists over the cause and implications.

The effects of climate change however, are there for us to see; the summer and autumn artic ice sheet is breaking up. On August 21, 2007 the Northwest Passage became open to ships without the need of an icebreaker for the first time, glaciers are retreating in many mountain ranges, freak weather events have become more frequent, the summer floods of 2007 in the UK an example and habitats and biodiversity is being destroyed. During my Nuffield travels I experienced temperatures of -25ºC in Sweden, a freak May snowfall in Germany, and freak rainfall in Iowa in May when much of the land was flooded.

Published in October 2006 The Stern Report, commissioned by Gordon Brown to look at the financial implications of climate change, reinforced already strong scientific evidence that climate change is taking place. Accelerated by human activity, the concentration of greenhouse gases; nitrous oxide, methane, but more notably carbon dioxide released by the burning of fossil fuels such as coal, oils and gas, in the atmosphere, has reached 430ppm. Pre industrial revolution levels were 280ppm. By absorbing heat these gases keep the earths temperature warmer than it would otherwise be. Unabated a level of 550ppm could be reached by 2035 which will result in a 2ºC rise in temperature. Unless it is tackled within a decade Stern concluded that climate change could cost the world £3.68 trillion.

The reaction of policy makers to the threat of climate change dates back 1994 with the United Nations Framework on Climate Change UNFCC, charging developed countries with the responsibility for addressing the problem. This was followed in 1997 with The Kyoto protocol. Countries that signed up accepted mandatory targets to reduce GHG emissions, with an emission target for 2012 and a 5% reduction over 1990 levels in the period 2008 to 2012.

The fundamental basis of the framework is to cap overall emission levels by assigning a monetary value to the atmosphere. Countries are allowed to trade carbon emissions, so a country within its limit can trade emission units to a country over its target.

In early December 2007 the United Nations Climate Change Conference in Bali culminated in the adoption of the Bali roadmap, which charts the course for a new negotiating process to be concluded by 2009 that will lead to a post-2012 international agreement on climate change. Ground-breaking decisions including the launch of an Adaptation Fund, technology transfer and on reducing emissions from deforestation were reached. Pressure on the US that has remained outside the group of developed countries who have embraced the Protocol was increased when Australia ratified the Kyoto agreement at the conference.

Bio fuels reduce carbon dioxide emissions when compared to fossil fuels and are an important measure in combating climate change and global warming.

6.2 Fossil fuel reserves and prices

In his state of the nation address in January 2006 George Bush declared that the US "was addicted to oil and alternatives had to be sought".

Oil reserves are finite, although there is no consensus within the industry of when the "end date" will be. Many geologists, including Jeremy Leggett the former Greenpeace scientist whose book "Half Gone, Oil Gas Hot air and the Global Energy Crisis oil", I read to gain an understanding of the subject, predict that peak oil production has been reached. Many Gulf States massively overstating their reserves to manipulate OPEC measures to limit oil production to % of total declared reserves. Latest estimates indicate 33 years of oil at current rates of use of 82 million barrels per day.

The situation for coal is a significantly better with an estimated 400 years of reserves, the problem for coal, however, is the emissions. Unless the carbon dioxide from its combustion can be captured, the reserves may be of limited use. In the face of increasing demand particularly for oil; China's consumption will double from 7 million in 2006 to 14 million barrels per day by 2025; India's requirements are set to increase fivefold to 5 million barrels per day by 2020 and as production falls, prices will increase. Fossils fuels will never run out; there are vast reserves of oil in the tar sands of Alberta, Canada, which have become economically viable as the price of oil has increased. Fossil fuels will just become expensive and uneconomic relative to other fuel sources. In early Nov 2007 oil price reached $98.62. One certainty; the threat of high prices fuels a race for alternatives.

(Figures Jeremy Leggett)

6.3 Energy security

The US has 8 military air bases in the Persian Gulf, and is currently spending $150 billion a year in Iraq and the Middle East on military activities. Little wonder when the US uses 25% of daily world oil consumption. OPEC countries control over 75% of global oil reserves. Are we wise to expect uninterrupted supplies of energy from unstable countries whose political regimes give cause for concern? Iran has 9.82% of the world's proven oil reserves, Iraq 8.5% and Saudi Arabia 19.5%. The US has a meagre 2.17%. Russia and Iran between them have over 45% of the world's proven gas reserves.

In 1990 65% of Europe's and 45% of America's oil was imported. In 2005 this had risen to 85% and 65% respectively. In Europe we have become totally reliant on gas from Russia or Russian pipelines delivering gas from Kazakhstan and further afield. A recent study by the Leipzig Institute of Energy Technology on the potential of biogas and gasification of biomass indicates that with appropriate energy efficiency measures by 2020 European gas consumption could be completely covered by biogas.

(Figures from The Pro Exporter Network and DLG)

6.4 Economic

The UK is now reliant on imports of energy from a wide range of countries; our economy is exposed to movements in energy price. Domestic production of bio fuels can reduce the risk of movements in energy prices causing inflation or depression in our economy.

Energy security is the main driver for bio fuels in the US, and Brazil but in Europe and the UK mitigating climate change is the motivation. Energy security does figure in some European countries, but you would question if that has figured on our government's radar, testimony to that the £750 million that has been spent on pipelines to transport gas from Liquid Natural Gas terminals built for the import of liquefied gas from Qatar. Would this have been better spent on supporting and developing a domestic biogas industry? Our complacency has resulted in the lack of investment in bio fuel technologies to take us beyond North Sea oil.

7. The market for bio fuels

Despite the increase in fossil fuel prices, in the majority of instances, (biomass for heat being the exception) bio fuels are still not economically competitive when compared to fossil fuels. Legislation setting out targets for bio fuel use underpins the market. In Europe, Directive 2001/77/EC set a target of 12% of energy consumption from renewables for the EU15 by 2010, of which electricity would represent 22.1%. Directive EU2003/30 set reference targets for blending of road transport bio fuels by energy content of 2% by 2005 and 5.75% by 2010. The most recent legislation sets out targets for 2020.

The US passed the Energy Policy Act in 2005. The Renewable Fuel Standard, providing loans and blending incentives of up to 50cents per gallon, laid out targets of 12 million tonnes of renewable fuel for 2006, rising to 22 million tonnes for 2012. All Brazilian petrol has to meet the legal alcohol target of 20-24%

In Europe an interesting comparison of the measures put in place to meet the European targets and the development of bio fuels in the respective countries can be made. The stage of development of Renewable energy and bio fuels in Germany reflects the strong support of the Renewable Energy Act (EEG) first implemented by Gerhard Schroder's Green Coalition in 2000. Although duty was introduced later in the year, bio fuels carried no fuel duty when I was in Germany in April 2006. Bio fuels and on farm straight rape oil as a diesel substitute (there is no concessionary fuel for agriculture) were widely used. Prices of up to 20 eurocents per kWh for electricity and contracts for 20 years supply from biogas plants have resulted in massive development of a farm based biogas industry. In Austria similar support measures are in place for electricity generated from biogas.

Although in Sweden there is direct support for bio fuels; government legislation that requires that bio ethanol E85 sells for 25% less at the pump than petrol. Bjorn Telenius of the Swedish Energy agency outlined more subtle measures in place. Bio ethanol-powered cars get free parking in many Swedish towns and cities, and are exempt from the pilot congestion charge programme in the capital city of Stockholm. Company car tax is also 20% less for environmentally friendly cars and 50% of government agency fleet cars must be vehicles that run on bio fuel.

7.1 UK Bio fuels legislation

In the UK there are two pieces of legislation that give bio fuels a guaranteed market:

1) **The Renewables Obligation (RO)** which has been in place since 2002 and places an obligation on licensed electricity suppliers to source an increasing proportion of electricity from renewable sources. In 2006/07 it is 6.7%, rising to 15.4% by 2015. Generators of renewable electricity are granted Renewable Obligation Certificates (ROC's) for each kWh of electricity they generate. ROC's are the means the suppliers have to demonstrate that they have sourced sufficient renewable electricity, and they are required to present sufficient ROC's to cover their requirement or pay a "buy out penalty" if they fall short which is recycled to the producers of renewable electricity. Regulation is the responsibility of OFGEM.

2) **The Renewable Transport Fuel Obligation** (RTFO) programme will, from April 2008, place an obligation on fuel suppliers to ensure that a certain percentage of their sales are

made up of bio fuels. The effect of this will be to require 5% of all fuel sold on UK forecourts to come from a renewable source by 2010. This will help meet our climate change objectives.

The RTFO is modelled on the existing Renewables Obligation in the UK electricity supply industry, with bio fuel producers granted Renewable Transport Fuel Certificates which fuel distributors have to present, or alternately pay a "buy out" penalty for falling short. The transport sector is responsible for 25% of emissions and through this initiative the government expects to reduce the carbon emissions from road transport in 2010 by about 0.7 - 0.8 million tonnes.

(Figures from the Department for Transport (DfT)

7.2 UK market for Road transport Bio fuels

The Department for Transport estimate that total UK diesel consumption in 2006 was 20.14 million tonnes. To achieve the RTFO obligation target for 2010 would require 1.007 million tonnes bio diesel. If produced domestically from rape oil that would require 2.9 million tonnes of oilseed rape. Total UK petrol consumption in 2006 is estimated at 17.89 million tonnes. Assuming current fuel usage to meet the RTFO obligation for 2010 0.895 million tonnes of ethanol will be required. 2.68 million tonnes of wheat will be required if this is produced domestically.

Note that the EU target is 5.75% by energy content bio fuel use (approximately 8% by volume), our government have cheated a little and our target is 5% by volume!

8 Economics and value chain first generation bio fuels

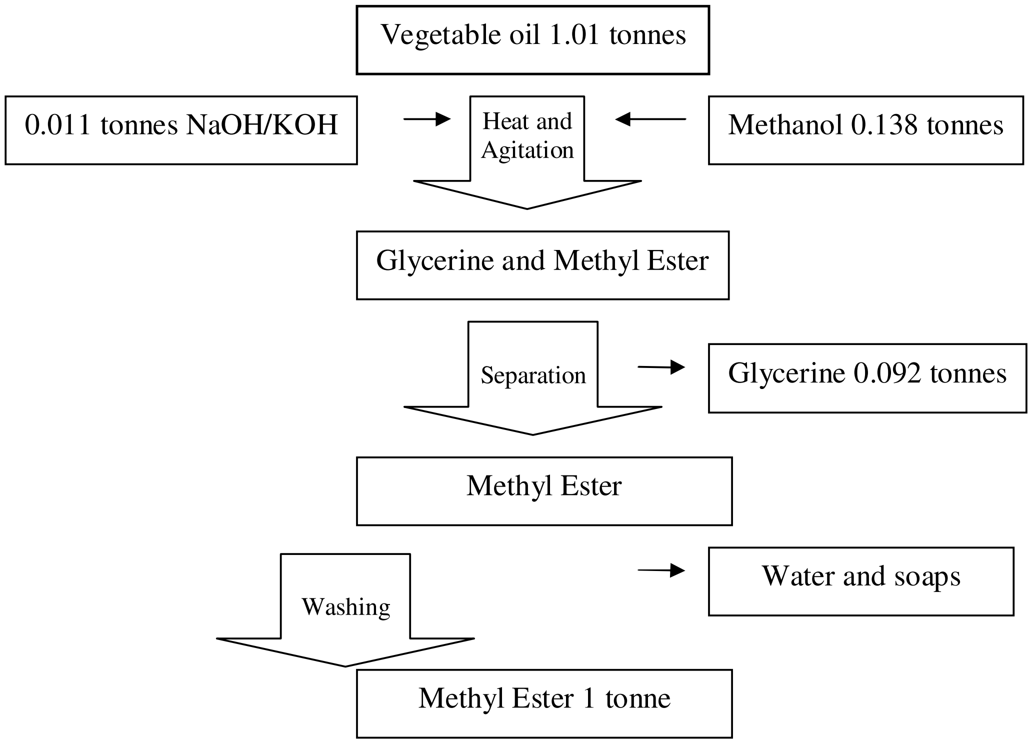
To get a picture of the viability of different bio fuels I have analysed the economics of bio fuels and the production plants that I have visited, in particular those relying on arable crops as their feed stocks. In the last year the impact of increasing commodity prices on the profitability of bio fuel production plants has been a cause of concern for investors:

8.1 Bio diesel

One of the first bio fuel plants I visited in Germany was Marina Bio diesel's 150,000 tonne /year plant at Brunsbuttle Germany. The plant which cost €15 million to build is owned by Schleswig Holstein Farmers Machinery ring. Although domestically produced rape oil is used in the Bio diesel manufacture, port facilities on the Keele canal adjacent to the site enable importation of cheaper palm and soya oil. Bio diesel plants I visited in Austria at Mureck and Gussing were following a similar trend blending used cooking oil with rape oil to reduce production costs. The value chain for bio diesel is summarised below;

In October 2007 refined palm oil was the cheapest virgin feedstock oil for bio diesel in Europe, with refined oil trading at 46p/l. Soya oil was marginally more expensive at 48p/l with rape oil at 55p/l (FO Lichts). Despite bio fuel producer's efforts to reduce their costs of production, in a competitive European market with surplus capacity due to the introduction of duty on bio diesel reducing consumption in Germany, there have been causalities in the UK already with Bio Fuels Corporation delisted from the Alternative Investment Market and Bio International at Immingham declared bankrupt in September 2007.

Bio diesel value chain



Cost of production Marina Bio diesel plant - tax and VAT adjusted for UK

	p/litre
VAT	13.3
Distribution	6.5
Duty *	30.1
Esterification	12.2
Vegetable oil (Rape oil)	53
TOTAL BLEND PRICE	**115.1**

**Bio fuels benefit from a 20p/l concession on fuel duty in the UK (Full road fuel duty 50.1 p/l). Even with this concession applied the cost of bio diesel is significantly higher than fossil fuel diesel.*

8.2 Bio ethanol

Bio ethanol production in Europe is centred on sugar beet and cereals as feed stocks, with production at a number of facilities in Germany, France and Spain.

8.2.1 Bio ethanol in France

At Bezancourt in the Champagne Region of France, farmers who own the sugar beet factory, have built an ethanol plant on the same site. The manager of the Crystal Union plant was reluctant to give me any detailed costs of production of ethanol, but informed me that production was geared towards paying farmers a minimum of €21/tonne for the beet they delivered. This was an acceptable price to farmers in an area where 80-100 tonnes per hectare of beet is easily achievable with the climate and soil type.

8.2.2 Bio ethanol in the US

In the US, 97% of the bio ethanol is made from Corn (Zea Mais) or whole grain maize as we know it. In May 2007 when I travelled through Illinois, Iowa, Nebraska, South Dakota and Minessota, 122 ethanol plants were operational, with a further 80 new plants or extensions in construction. Production in 2008 is set to hit 13 US billion gallons.

In May 2006 Lincolnway Energy's 50 million gallon per year dry mill ethanol plant adjacent to the East West Lincolnway, and Union pacific railroad in Central Iowa commenced production. Drawing corn from a 30 miles radius, 900 investors who initially invested $25,000 own the plant. Plant manager Dr Larrs Dunn has spent his entire career working in the ethanol industry and is proud of the financial results; in the first six months trading a profit of $15.9 million was reported. The plant uses coal as its energy source, which raised the total build cost by $15 million to $78 million. Using 250 tonnes of coal per day to provide heat for the distillation process reduces energy costs to less than a third of an equivalent plant running on gas.

Dr Larrs Dunn – Manager Lincolnway Energy

An important distinction; Lincolnway Energy is a dry mill plant the most common in the US. Corn is milled and all the milled material goes through the fermentation and distillation process resulting in the production of large volumes of distillers grain solubles as a by-product of the process. Carbon dioxide is also produced in fermentation. At Lincolnway Energy, with access to cheap energy, distillers grains solubles are dried and loaded onto railcars for transit to Idaho and Wisconsin where they command a price of $100/tonne for feeding dairy cows.

The larger 200 million gallon ethanol plants of Archer Daniel Midland (ADM) and Aventine use a wet mill process, whereby the corn is separated into starch, protein, germ and fibre in an aqueous medium prior to fermentation. The primary products of wet milling include high fructose corn syrup, ethanol, corn oil and corn gluten.

The discovery that methyl tertiary-butyl ether (MBTE), a traditional fuel oxygenate was polluting groundwater, and its subsequent banning paved the way for ethanol as a replacement fuel oxygenate in many US States. Whilst corn prices remained low the sudden increase in demand and high ethanol prices (up to $5/gallon – 70p/l) attracted Wall Street investment. Pay back periods on investment of less than a year created the fastest growing industry in the US. A 50 cents per gallon blending subsidy and capital grants have helped finance new plants and have contributed to the speed of development; Nebraska has become the third largest state ethanol producer, growth helped by a state program giving $25 million capital support for ethanol plants over 7 years.

A barometer of the money made; pre tax profits of ADM the largest producer of ethanol in the US hit US $2.287 billion for the year ending June 07, a three fold increase on 2004.

The ethanol boom times are however over, at the time of writing the Chicago Board of Trade futures price for Ethanol is $1.70 per gallon, which equates to 23 p/litre or £291/tonne, the price has been pushed down by oversupply and the oxygenate market having been fulfilled in many US states. With the massive increase in corn prices in the last year (corn is now $4/bushel) some plants have been shut down and there have been some bankruptcies.

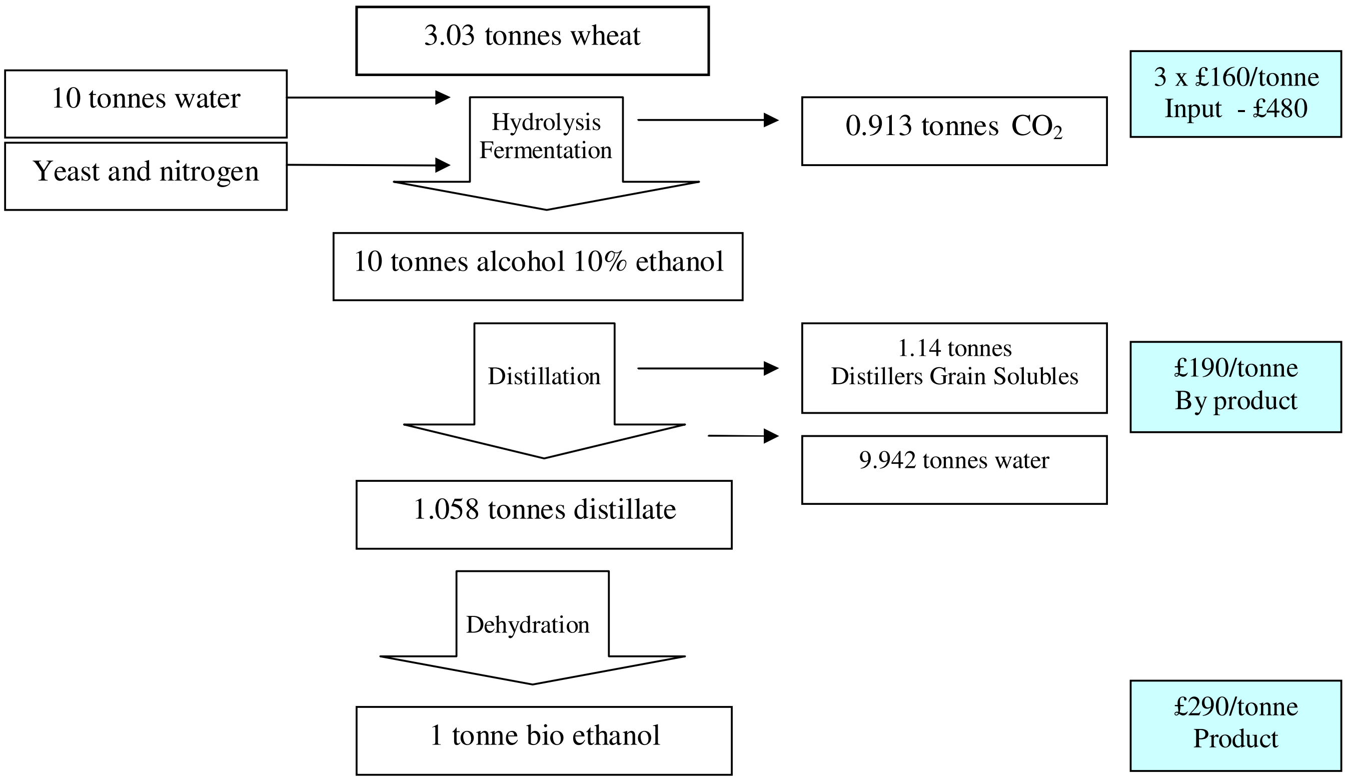
8.2.3 Bio ethanol produced from wheat in the UK - value chain

In August 2006 I acquired an investor memorandum for a bio ethanol plant in the UK. The business model was based on wheat at £79/tonne and ethanol at 38 pence per litre. Three tonnes of feed wheat are required to produce 1 tonne of ethanol, with 1.14 tonnes of distillers grain solubles the by product which can be used as animal feed. Without any of the production costs the input costs of the process are the same as the output value; the cost of production of ethanol from wheat is currently 34 p/litre; ethanol is worth 23p/l.

We have an exportable surplus of cereal grains in the UK of roughly 3million tonnes per annum, this could produce all the ethanol we need but are we right to do so when ethanol can be made from sugar cane in Brazil for as little as 12.5p/l..?

The price increases for the commodities used to make bio fuels will self limit their production, it is unlikely that ethanol production from wheat will be viable in the UK. This explains the slow progress that many of the planned plants have experience and the struggle they have had to attract investors.

Bio ethanol value chain



8.3 Rape oil used as a fuel - Germany

In Germany there is no duty on vegetable oil used as a fuel and also no concessionary fuel for agriculture. A rebate system whereby the farmer receives a refund of 50% of the duty on 10,000 litres of fuel, approximately €2100, coupled with a price differential between rape oil and diesel of up to 35 eurocents per litre up to 2006 has stimulated a new market for the use of rape oil.

Long field hours under full load suit engines running on rape oil. Many German farmers now cold press rape seed on farm, filter the oil and use it as a fuel in tractors, selling any surplus. Rape meal finds a home as animal feed or in some instances as a substitute for wood chip or pellets in biomass boilers.

Max von Laer manages 1300 ha of land at Füstenburg in Rhine Westfalia for the Graf von Westphalen family. Nine hundred tonnes of rape are produced on 220 ha of land in a rotation with cereals and sugar beet. In 2004, to reduce fuel costs, the estate bought three Kernkraft cold presses for €15,000 each. Running continuously, the 10kg hour presses work their way through 265 tonnes of rape each annually, producing 90,000 litres for farm use.

Oil extraction of 32% by weight, equating to 34 litres per 100 kg rape has been achieved by preheating the rape by running through a water heated jacket before pressing. The Kerncraft presses exude the meal in a pellet form. Rape oil is filtered by adding chalk in two converted trace element bulk containers, agitating and then passing through a Kammer filter press. Rape oil is stored in two old fibreglass wine tanks and then distributed to tanks and machinery through a bowser. The equipment fits neatly into a traditional grain store, utilising bins and conveyors that would otherwise be obsolete as the farm has invested in a new grain store.

Modifications to fuel systems which are necessary where 100% rape oil is used are well proven, German manufacturer Elsbett have been in the market for over 20 years. Mr Von Laer has installed a Räpstruck twin tank system on his four John Deere tractors. The engine starts on fossil fuel diesel, stored in a separate small tank and swaps over to rape oil when the engine temperature reaches a level sufficient to reduce the viscosity of the rape oil. Before stopping the engine, the system swaps back onto diesel, purging fuel lines ready for restarting. A Beam Plus system on the farms Fendt Vario 920 uses a heating element to pre heat the rape oil before it enters the fuel system. After 850 hours work an engine test station examination of the combustion chambers on the Fendt showed no deposits, with injection nozzles functioning properly.

Although some manufacturers of the modification kits will underwrite engines, Mr Von Laer is not deterred by invalidation of warranty, the significant savings to be made more than compensating for the risk. He is reluctant to use "raps" in his combine as he has been advised that rape oil does not work well with common rail fuel systems.

After two full seasons of using rape oil Mr Von Laer is pleased with the savings that have been made, (see below) with few problems. However, the significant increase in rape prices in the last year has reduced the savings to a level that only covers the cost of the conversion units over the life of the tractor. He also cites his contribution to reducing carbon dioxide emissions as a positive, but with no value attached to that.

Kern Kraft rape presses exuding rape meal in a pellet form

Cost savings

The tables below summarise the cost of production of rape oil in 2006 with oilseed rape at £180/tonne, and in 2007 at £250/tonne. The cost of production of the rape oil has increased by 20p/l to £0.74 in 2007. This has reduced overall annual savings to £1,600.

At Füstenburg, rape meal from the presses is sold for animal feed, but some has been used as a replacement for wood pellets in a 45 kw pellet boiler in the basement of Mr Von Laer's house. The rape meal has an energy content of 5.3 kwh/kg. With a saving of almost a penny per kwh heat, Mr Von Laer stands to make a saving of £1,300 per year on his heating bill.

Graf von Westphalen - Oil pressing costs per kg rape pressed

	2006 rape @ £180/tonne	2007 rape @ £250/tonne
Electricity	£0.008	£0.008
Parts and repairs	£0.025	£0.025
Oilseed rape @ £250/tonne	£0.180	£0.250
Labour	£0.005	£0.005
Rape meal @ £85/tonne	-£0.0570	-£0.0570
Depreciation (5 years to zero)	£0.020	£0.020
Net price per kg rape pressed	**£0.181**	**£0.251**
Litres oil per kg rape	0.34	0.34
Price per litre rape oil	**£0.5328**	**£0.7387**
Von Laer system 3 x Kernkraft presses and a Kammerfilter press Total capital expenditure £30,000		

Graf von Westphalen Cost comparison diesel - rape oil

			Price 2006	Price 2007	Total cost 2006	Total cost 2007
Total fuel consumption 90l/ha on 1300 ha		117,000l				
Diesel consumption		107,000l	£0.75	£0.78	£80,545.32	£83,674.00
Fuel rebate of 0.2148 €		10,000l	£0.61	£0.61	£6,065.60	£6,065.60
Total fuel costs					**£86,610.92**	**£89,739.60**
Rape oil alternative:						
Diesel for winter months and combine		20,000l	£0.75	£0.78	£15,055.20	£15,640.00
Fuel rebate of 0.2148 €		10,000l	£0.61	£0.61	£6,066.96	£6,066.96
Rape oil consumption 5% more than diesel		89,610l	£0.53	£0.74	£47,529.14	£66,418.93
Total fuel costs					**£68,651.30**	**£88,125.89**
Annual fuel cost saving					**£17,959.62**	**£1,613.71**
Tractor conversion costs						
Fendt 920	Beam plus pre heater		£1,700.00			
JD 7720	Twin tank Rapstruck		£3,060.00			
JD 7920	Twin tank Rapstruck		£2,380.00			
JD 8520	Twin tank Rapstruck		£2,380.00			
JD 8300	Twin tank Rapstruck		£2,380.00			
Total capital expenditure			**£11,900.00**			
Payback period 2006	Years		1			
Payback period 2007	Years		7			

(Information for preparation of figures supplied by Max Von Laer)

8.4 Biogas

It is difficult to travel in Germany without noticing the numerous farm based Biogas plants; there are now over 3500 on farm plants which in 2007 will have produced approximately 10 billion kWh of electricity. The German on farm biogas concept is based on the anaerobic digestion of crops grown specifically for energy such as maize and grass silage or whole crop cereals. Where cattle or pig slurry is available as a base medium it is used. The biogas is mainly used to fuel gas engine CHP units to generate electricity. Austria also has over 300 on farm biogas plants.

The Swedish biogas industry is somewhat different, with centralised biogas plants digesting the organic fraction of municipal waste supplementing with energy crops. In many instances the biogas is upgraded and compressed for vehicle use.

Typical biogas plant size in Germany is 500 kW, with 10,000 tonnes of maize silage sufficient to feed the plant being grown on 200ha of land.

8.4.1 Hollern Biogas plant

Josef Pollmann is an organic farmer and manager of a biogas plant at Hollern, 35km East of Vienna. In 2004, 28 farmers in the Hollern area formed a cooperative and raised £136,000, borrowed £1.36 million and secured £68,000 of funding from Lower Austria, to build a 500 kW biogas plant. Feedstock for the plant is maize silage grown on farms up to 4.5 km away from the plant, and harvested by a self propelled forager shared with 3 other biogas plants in the area.

Josef Pollmann in front of the 500 kW gas engine of the Hollern Biogas Plant

Benefiting from a 10 year contract with EVN the regional power company and a guaranteed electricity price of £9.9/kWh, before accounting for the value of the maize silage produced for the plant, a profit of £190,400 was made in 2006. The aim of for the plant is not to make any money, with the profits to be distributed to the members of the cooperative through payment for the maize they supply; £19/tonne in 2006. This did compare favourably to whole grain maize when it was worth £65/tonne, not the case now!! Due to the location of the plant heat energy from the CHP gas engine is not utilised and dissipated through heat exchangers. If a connection could be made heat energy could be sold to a nearby village with a district heating network for 1.43 p/kWh.

8.4.2 Hoheneggeslsen Biogas plant

Hoheneggeslen Biogas plant is owned by 23 farmers and is approximately 40km South of Hanover in Lower Saxony. The 500 kW plant digests maize silage, feeding electricity into the national grid, on a 15 year contract with a price of £0.136/kWh. Heat energy is used to dry sludge at the adjacent sewerage works. When I was in Germany I attended the meeting where the farmers agreed to go ahead with the project, not that I understood a great deal!! Christian Stoewenau the manager is now a good friend and I have been back to the plant twice since I was originally there. This has given a great opportunity to see the affects of the changes in commodity prices that have occurred.

Biogas plant operational figures

Biogas plant profit calculation	**Hollern Biogas Plant Austria**	**Hoheneggeslsen Biogas Plant Germany**	
		2006 Maize price	**2007 Maize price**
Plant costs	£1,564,000	£1,700,000	
Electricity value (/kWh)	£0.099	£0.136	
Plant size (kW)	500	500	
Hours generating per day	24	24	
Days generating per year	328	328	
Hours generating per year	7872	7872	
Tonnes of Maize silage required	10,000	10,000	
Cost per tonne	£19	£17	£25
Total cost of Maize silage	£190,400	£170,000	£250,000
Income per day	£1,183	£1,632	
kWh per year	3,936,000	3,936,000	
Total income per year	£387,600	£535,296	
Annual running costs	£68,000	£74,800	
Maize feedstock	£190,400	£170,000	
Profit before interest and finance	**£129,200**	**£290,496**	**£210,486**
Bank repayments and interest	£129,200	£140,435	

(Information for preparation of figures supplied by Josef Pollmann and Christian Stoewenau)

> ***Note:*** *These calculations do not place any value on the digestate which is the by product of a biogas plant, a voluminous slurry containing up to 4, 1.75 and 0.75 kg/cubic metre of nitrogen, potash and phosphate respectively.*

8.4.4 The increasing cost of feedstock dilemma

The feasibility study for the Hohenneggeslsen Biogas plant was done when cereals were worth £75/tonne, and oilseeds were worth £140/tonne. The first maize crops were grown in 2006, and farmers were happy to deliver maize silage to the silos at the plant for £17/tonne, as this gave them a comparable gross margin to oilseed rape, their other break crop. With rape now worth

£238/tonne the price required for maize silage delivered to the plant to achieve a comparable gross margin is over £25/tonne; plant profitability has been reduced by £80,000.

German Energy crop Maize Gross margin compared to Wheat and Oilseed rape

		Winter Wheat	Maize	Rape
Output	Yield t/ha	9.5	48.0	4.5
	Price £/t	£152.32	£17.00	£238.00
	Sub Total	£1,447.04	£816.00	£1,071.00
	Energy payment	£0.00	£30.60	£30.60
	Total	**£1,447.04**	**£846.60**	**£1,101.60**
Variables	Seed	£40.80	£91.80	£68.00
	Sprays	£95.20	£27.20	£95.20
	Fertiliser	£148.40	£166.00	£128.40
Operations	Base operations	£139.40	£107.44	£139.40
	Harvesting	£74.80	£163.20	£74.80
	Haulage	£27.20	£61.20	£13.60
	Clamp/Storage	£0.00	£20.40	£13.60
Misc	Ensiling	£0.00	£47.60	£0.00
	Total costs	**£525.80**	**£684.84**	**£533.00**
	Net margin	**£921.24**	**£161.76**	**£568.60**

***Note**: to achieve a gross margin equivalent to rape the price for maize must be £25/tonne*

The wholesale price for electricity in Europe is 3.7p/kWh. You might question the sense in paying German farmers 13.6 p/kWh to grow energy crops and digest them. The high price is only achieved if the plant utilises heat energy and uses new technology, with the base tariff at 9.5p/kWh. This underlines the importance of CHP, utilising heat energy, which in the case of biogas even after using some of the heat to warm the digestors to 38ºC, will be of similar quantity to the electrical output.

Regardless of country or bio fuel with current fossil fuel prices subsidy or tax breaks are required to make bio fuels competitive. Even then in many cases production economics are very marginal especially with higher commodity prices.

9. Efficiency and environmental impact of bio fuels - Energy balances and greenhouse gas (GHG) reductions – Bio fuels for road transport

9.1 Energy Balance

The environmental influence of energy production is critical; the concept of energy yield and energy balance describes how profitable bio fuel production is in terms of energy economy. There is much debate within the bio fuels sector over the energy balances and greenhouse gas reductions of bio fuels for road transport relative to fossil fuels. David Pimentall of Cornell University has done much work on the subject, with some negative reports particularly on corn ethanol. It became apparent when I discussed this work with ethanol producers in the US corn belt that his work included exhaustively all the energy consumed, but neglected the co product energy content such as distiller's grain. This value should be included in the energy balance.

The general consensus is that most systems of producing bio fuels have a positive, albeit small energy balance. That is, more energy is produced from the bio fuel than was consumed in the growing of the material the bio fuel is made from and the conversion process. Analysis is standardised on the "Field to Wheel" concept which includes all input carbon and energy costs from planting to use as a fuel.

The analysis depends on fertiliser manufacture (nitrogenous fertiliser use in arable farming accounts for up to 50% of energy used) cultivation system and bio fuel production process. Crop yield also has a significant impact. There is scope for improvements in efficiency if growing is targeted at the bio fuels market; wheat with low protein and high starch content.

The following summary of energy balances is a combination of International Energy data, Lund University of Sweden and Pro Exporter Network information.

Net Energy balance, Energy Output v Energy Input ratio by feedstock

Bio fuel	**Ratio**
Wheat ethanol	1.2
Corn ethanol	1.67
Sugar beet ethanol	1.9
Sugar cane ethanol	8.3
Cellulosic ethanol	2
Petroleum	0.81
Oilseed bio diesel	3.2
Diesel	0.83
Biomethane (Compressed biogas) energy crop	2.4
Biomethane (Compressed biogas) organic waste/slurry	3.6

For ethanol production tropical plants such as maize and sugar cane with their C4 physiology are more efficient producers of bio fuels than temperate environment crops such as wheat. Short rotation coppice for heat and power production has an energy balance ratio of 19.

9.2 Greenhouse gas (GHG) reduction

The ability of bio fuels to reduce GHG emissions is essential in mitigating climate change. Analysis is based on the comparison of 'Well to Wheel' assessment of a fossil fuel versus the 'Field to Wheel' assessment of a bio fuel. 'Well to Wheel' is the impact of a fossil fuel including the total GHG emissions of the oil well during exploration, production, transportation, refining, storage, distribution, retailing fuelling and tailpipe emissions from the vehicle. 'Field to Wheel' assessment of a bio fuel includes lifecycle GHG emissions including carbon storage of different land use types, emissions from energy generation needed for irrigation, use of fertilisers, insecticides, herbicides, fungicides, planting and harvesting of crops, storage and transportation to the bio fuel plant. The analysis shows carbon dioxide to be saved when compared to the use of fossil fuel.

Jeremy Woods of Imperial College has produced a GHG calculator for wheat ethanol for the HGCA
http://www.hgca.com/content.output/2135/2135/Resources/Tools/Bioethanol%20Greenhouse%20Gas%20Calculator.mspx

The following table shows bio ethanol and bio diesel provide significant reductions in GHG emissions compared to their fossil fuel equivalents, with the greatest savings made in ethanol made from sugar cane, and biomass to liquid second generation bio fuels.

Reduction in carbon dioxide equivalent GHG/km compared to petrol/diesel

Bio fuel	GHG reduction
Grain ethanol	20-45%
Sugar beet ethanol	30-50%
Sugar cane ethanol	85-90%
Cellulosic ethanol	60-100%
Rapeseed Bio diesel	45-65%
Cellulosic Bio diesel	80-90%
Biomethane (Compressed biogas) energy crop	75%
Biomethane (Compressed biogas) organic waste /slurry *	200%

** The reduction in greenhouse gas is two fold:- A reduction in emissions of methane if the organic material or slurry broke down naturally releasing methane (methane is over 20 times more damaging as a GHG than carbon dioxide), and the reduction in emissions for methane used as a fuel in comparison with fossil fuels.*

Source REA, Choren Industries and National Society for Clean Air (NSCA)

In 2008, the RTFO will place a requirement on bio fuel producers to supply information on the GHG savings and sustainability of the bio fuels they supply. The carbon intensity of production of the crops used to manufacture the bio fuels have been rated. In the case of bio diesel, oilseed rape oil is not rated as well as palm or soya oil, due to the amount nitrogen oilseed rape requires.

10 "Food versus fuel"

Thomas Malthus published his Essay on the Principle of Population in 1798. Malthus's key insight was simple but devastating; unchecked, population would grow far more rapidly than food production. "The vices of mankind are active and able ministers of depopulation," some critics would argue that bio fuels are a vice of mankind, and that use of land to produce grains and oilseeds for their production will lead to starvation.

To appreciate the effect on land use that bio fuels have had the dynamics of corn production in the US is the best, if most extreme illustration. In 2006, the US grew 31.7 million hectares of corn, producing 273 million tonnes, with 54.6 million tonnes used in ethanol production, approximately 6.34 million hectares for bio ethanol. That figure is set to rise to 120 million tonnes in 2008, over twice the area for ethanol production (USDA figures).

At Bloomington, Illinois, in April 2007 I was fortunate to hear Lester Brown of the Earth Policy Institute speaking about the threat that bio fuels presented to food security: His estimate, 2006 cereal production was 73 million tonnes short of consumption. In six out of the last seven harvests, cereal grain production has fallen short of consumption with carry over stocks down to 57 days, the lowest in 34 years. The last time this happened grain prices doubled – I wish I had listened and bought some wheat futures! Coupled with some climatic effects; the continuing Australian drought and closer to home freak summer weather in July 2007 the Office for National Statistics reported that seasonal food prices have risen by 10pc in the previous year. Overall food and drink costs are up by 6% - the highest rate in the Western world, according to the Organisation for Economic Co-operation and Development (OECD).

I experienced the "food versus fuel" effect first in May 2006 near Bremen in Germany, an area heavily populated with pigs and poultry with a large area of grain maize grown to feed the livestock, but also due to the slurry available an area with many biogas plants. Competition for land to grow grain maize for animal feed and maize silage for biogas had caused land rents near biogas plants to rise from €400/ha to €600/ha. The Deutscher Landwirte Geschelschaft (DLG) estimates that over 300,000 hectares of land are used in Germany for producing energy crops for biogas plants. Ethnaol has driven "cash rents" up in the US.

10.1 Bio fuel production per hectare

With competition for land to satisfy food and energy needs the most efficient crops for bio fuels must be grown. In simple terms, the total yield of bio fuel feedstock such as vegetable oil produced per hectare is important (see below), but consideration needs to be taken of energy required in production; Soya delivers a poor oil yield per hectare, but is a crop that can be grown without any nitrogenous fertiliser.

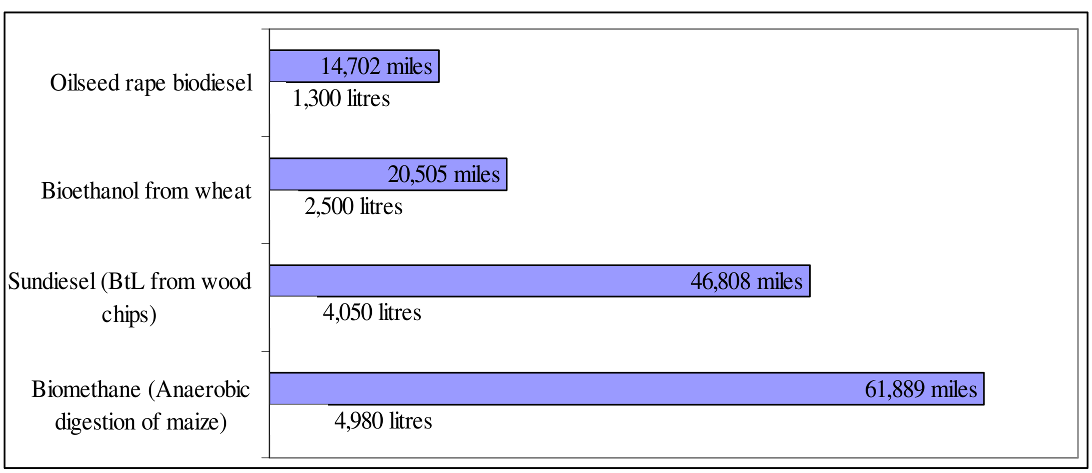
Yields of common oil crops and oil cost

Crop	Oil yield litre per ha
Soyabean	370 – 470
Sunflower	950 – 1050
Jatropha	1600 – 1800
Oilseed rape	1000 – 1400
Refined Oil Palm	6,000
Algae	95,000

Source - Global Petroleum Club and UFOP and FO Lichts

Different bio fuels will give a different potential fuel yield per hectare, and to demonstrate this consider the distance travelled by a VW Golf running on bio diesel, bio ethanol or bio methane (upgraded biogas) produced from 1 hectare of land. Bio methane tops the chart. Merely looking at land use efficiency of a bio fuel is however not enough. Lifecycle emissions, fuel production costs, scaling options and the need for adapting fuel distribution infrastructures and vehicle modifications need to be taken into account. In Germany, in 2006 of the 56 million motor vehicles on the road, only 35,000 were able to run on Biogas, and there were only 650 biogas filling stations. In Sweden, a Volvo V70 bi fuel to run on diesel or biogas in February 2007 cost £2,300 more than the straight diesel model.

Distance travelled by a VW Golf with different bio fuels produced on one hectare of land
(Information from Fachagentur Nachwachsende Rohstoffe e. V. (FNR)



10.2 How much bio fuel can be produced with current technology?

The International Energy Agency's World Energy Outlook in 2006 concluded that approximately 1 per cent of the world's available arable land was supplying 1 per cent of global transportation fuels, along with by-products such as rape meal and distillers grain solubles for animal feed.

I mentioned earlier that to achieve the UK RTFO targets for bio fuel use by 2010 from domestic production 2.9 million tonnes of rape and 2.68 million tonnes of wheat would be needed. In early 2007, the EU agreed a draft energy plan that includes a binding bio fuels target of 10 per cent (by energy content) by 2020. Ignoring our Government's fiddle of volume and energy!! (see earlier) 10% bio fuels by volume domestically produced would required 5.8 million tonnes of oilseed rape and 5.36 million tonnes of wheat. In 2006 we had a little over 500,000 hectares in set aside in the UK. If all of this came back into production and with our current exportable surplus or cereals we would not be able to achieve this target without significant imports.

A recent study by CONCAWE (European Oil Refiners Association) into the future automotive fuels in the European confirms my assessment; if all set-aside land and all cereal and oilseed exports in the EU were diverted to bio fuels, a maximum of 4 per cent of conventional road fuels could be substituted; 27% of projected EU cereals production in 2012 would be needed to meet the 5.75% petrol/diesel replacement target.

To get things into perspective if all the corn in the US was converted into ethanol it would only satisfy 21% of gasoline needs. With current technology and yields, bio fuel production to supply more than 5-10 per cent of transportation fuels would risk seriously impinging on food supply and bring about major land-use changes. Any expansion of bio fuels must also be considered carefully in the context of other major pressures on land use and food prices, including:

- **Rising global population and incomes,** leading to increased demand for food. The United Nations estimates that the world population will grow to around 9 billion in 2050 up from 6.5 billion in 2006;
- **Changing global diet** towards meat and dairy products, which require large inputs of grain for animal feed;
- **The consequences of climate change,** reducing yields and increasing droughts insome regions reducing potential supply.

10.3 Impact on commodity prices

It would be nice to say something revolutionary, but events have overtaken my report: Taking December 2005 to December 2007 as a reference period, rape and wheat have increased in price by 50% and 60% respectively. The million dollar question; what will happen in the foreseeable future?

From my travels I am optimistic; investors don't spend millions on bio fuel plants, for them to stand idle, moreover in the US due to the massive profits and payback already achieved, ethanol plants can weather the current low ethanol prices. Many plants are owned by farmers and their obligation to grow crops for feed stocks commits land to energy production. Oil and energy prices are likely to continue to rise and bio fuels will catch up. Ethanol prices have suffered, in particular due to the glut in the US where rapid growth in production and limitations of infrastructure such as a straining rail road to move ethanol from the Midwest to the East and West seaboards has not helped. Reece Nanfinto of the Ethanol Promotion and Information Council (EPIC), Omaha, Nebraska, identified new markets for ethanol in Florida and Georgia in 2008 due to rule changes for fuel oxygenates. Ethanol has become too important to the US for energy security and also rural prosperity. A typical ethanol plant in the Mid West will provide employment for 50 people in rural communities that have been depopulating since the 1930s.

I recently read a report by Credit Suisse, "Higher Agricultural Prices, Risk and Opportunities" that confirms my optimism. Estimating that global food production needs to grow by 2.5% per year to keep pace with the dietary needs of population and adding the demand for agricultural produce created by bio fuel expansion (government set bio fuel targets commit 12% of the total arable area over the next 10 years) they reach a figure of 3.3% growth in agricultural production to satisfy demand. This is not being met by global agricultural production at present and does not look likely to be.

11 Is the world's population going to starve?

Provocative statements such as *"A Culinary and Cultural Staple in Crisis, Mexico Grapples with Soaring Prices for Corn -- and Tortilla"* have occupied column inches in the last year, so the ethics of bio fuels was a subject that I wanted to investigate when I was in the US corn belt. Will there be enough corn to go around, and what of the food versus fuel debate? Questions I asked people I met. The corn belt defence for the 40% increase in tortilla prices in Mexico – tortilla is made from white corn, ethanol yellow, white corn is grown on specific contracts. One tonne of corn will feed 4 people for a year or produce enough ethanol to fuel a Hummer H5 sports utility vehicle for 1350 miles.

Illinois State is a big exporter of corn with the barges loaded on the Mississippi River having access to the Gulf of Mexico. According to Rod Weinzierl, Chief executive of Illinois Corn Growers Association "the shackles are coming off agriculture, and the market and a $4.5/bushel corn price will result in sufficient corn being available to satisfy food and fuel requirements".

Despite this sentiment, for the first time in their history Illinois Corn Growers Association circulated a memo to encourage farmers to grow corn in 2007. Farmers responded in Illinois and across the US with the spring sowings of 92.9 million acres, the highest since 1944. The main losers in this big cropping shift. Soya, down by 2.1 million acres in Illinois and Iowa alone, Cotton, and land coming out of the Conservation Reserve Program the US program for long term fallowing of land.

Bill Northey, the Iowa Secretary of Agriculture, who I met in Des Moine, the capital of Iowa State, highlighted an important point in the challenge of producing enough corn for fuel and human consumption. The large profits that the ethanol industry has enjoyed have enabled much money to be invested into research. Ethanol plants stand to gain a huge amount if they can convert the pericarp of corn into ethanol, and raise the ethanol yield from the standard 2.7 gallons per bushel. This technology will be commercialised and ease the pressure on demands for corn for ethanol. Bill also enlightened me, explaining the Iowa Caucus importance in the presidential election, and how all potential presidential candidates left the state with a pro agricultural view!!

Agriculture is faced with a huge challenge to meet the increased demand. We were faced with starvation in the early 20th century for the lack of fertiliser. Incessant innovation is a characteristic of human beings, we have been creating ecological crises for ourselves and our habitats for tens of thousands of years and we have been solving them too. From what I have seen I believe the challenge will be met. In the next three sections of this report I summarise some of the reasons why: technological advance, energy from waste and land coming back into production.

12 Technology

12.1 Second generation bio fuels – Biomass to liquid (Btl), gasification

Choren industries are the world leaders in gasification technology; through a two stage process using pressure and high temperatures the carbon, hydrogen and oxygen in biomass are converted into a syn gas which is made up of 35% hydrogen, 35% carbon monoxide and 25% carbon dioxide.

The syn gas can be used as a fuel in a gas engine to generate electricity, or can be converted into a liquid fuel by the Fischer Tropsch process, a catalytic cracking reaction. The technology is not new and was developed in the 1930s in Germany to produce diesel from coal and wood. Its use continued in South Africa, but due to the cost and availability of fossil fuel diesel was discontinued in Germany. Fischer Tropsch technology has seen a comeback with the conversion of natural gas to liquid fuels; Shell V Power diesel has gas to liquid produced diesel blended in it. Choren’s first biomass to liquid fuel plant at Freiberg, Germany, was still under construction in September 2006 when I visited. When operational it will convert 75,000 tonnes of wood chip a year into 15,000 tonnes of synthetic bio diesel which Choren have named Sun diesel.

Choren Industries plant at Freiberg

The estimated costs of production of Sun diesel are 55-60 pence per litre. The plant will produce 45Mw of thermal energy that will be utilised for heating and industrial processes. Through a strategic partnership with Shell, five further plants in Germany each costing £275 million, will produce 200,000 tonnes of Sun diesel from 1 million tonnes of recycled wood from biomass; straw, rape meal, sawmill residue and woodchip are planned.

EEG gasification plant at Güssing

Güssing in Austria is the location of the European Centre for Renewable Energy. The EEG gasification plant has been operational for four years, with the syn gas produced from locally produced wood chip used to fuel a gas engine that generates 2Mw of electricity with 4Mw of heat energy used in the town's district heating network. The plant is a prototype and in 2006 had broken-even financially after initial technical problems.

Ethanol from cellulose

Despite all the hype about ethanol production from corn in the US there is recognition of the need to find alternatives. Ethanol produced from switch-grass, a native prairie grass and corn stalks are alternatives widely discussed. The Federal Government are funding six projects of $80 million each to commercialise ethanol production from these cellulose materials. Ethanol produced from cellulosic materials has to date focused on the use of enzymes, acid hydrolosis or thermophiles to break the cellulose down into sugars that can be fermented. Abengoa and Iogen are companies leading the technology, with Abengoa commissioning a prototype straw to ethanol plant in Spain in 2007. UK based company TMO Thermophiles have developed a thermophile to break down cellulose and have a joint venture to build a plant at Rotterdam in Holland.

Professor Robert Brown is a Mechanical Engineer specialising in thermal process engineering and gasification at Iowa State University. He questions if the structural material of plants and nature were ever intended to be broken down, and be commercially converted to ethanol. The technology has been in existence with an experimental plant developed at Quad City Iowa in 1941, but has never been commercialised to date in the US.

A possible reflection of this is the channelling of the Federal Governments funding of second generation bio fuels into gasification technology. Syn gas can be converted into ethanol as well as bio diesel. Professor Brown pointed out the developments in gasification of biomass; the first 80% of any biomass material converts to a syn gas easily, the remaining 20% requires huge energy input. Not converting the last 20% and returning it to land as a charcoal soil conditioner to increase organic matter in Corn Belt soils that are suffering organic matter depletion is the answer in his view.

Second generation technology represents a significant and very necessary development. It is wrong to think that once second generation technology is widespread whole swathes of the corn belt will be growing switch-grass and in East Anglia, miscanthus and willow will be widespread because these crops produce more biomass per hectare. Where is it possible to grow high yields of cereal grains or oilseeds, they will be grown. Second generation technology will enable the crop residues; straw and corn stalks to be used for bio fuel production and take pressure off the use of cereal grains and oilseeds in its production.

Second generation technology will enable higher conversion rates in existing bio fuel plants, where the pericarp of cereal grain will be converted to ethanol. Timber from forest thinning, wood waste and waste paper will also become viable feed stocks. Marginal land for cereal grain and oilseed crop production will be able to grow biomass for bio fuel production. Commercialisation of the technology will enable the volumes of bio fuels we require to be produced without impinging on food production. It does however introduce some logistical problems; consider, in the case of Choren Industries sun diesel plants, getting 1million tonnes of biomass, a bulky material into a plant annually.

12.2 Genetic modification

I visited many farmers in Illinois, Iowa, Nebraska and Minnesota in April/May 2007. A common theme for them all; increasing corn area (at the expense of soya), increasing use of GM corn, and increasing yields, up 20 to 30 bushels per acre.

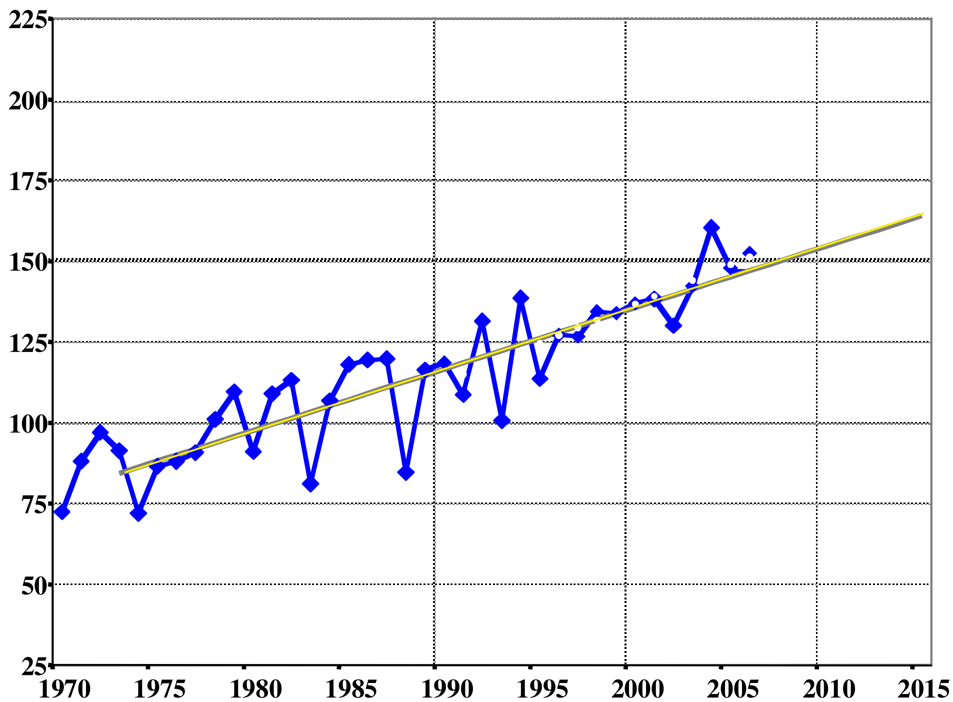
Pioneer Seeds, based at Johnson, Iowa, have 25% of the global corn seed market. Bill Lloyd, Development Manager, gave me a tour of the amazing breeding facility there. Pioneer market over 300 corn hybrids in America; 180 are specifically for ethanol production. Yields are increasing at an amazing rate and are predicted to reach an average of 164 bushels per acre by 2015.

“Triple stacked” corn has three genetic modification characteristics: resistance to corn root worm, resistance to European corn borer and is liberty link/Round-up tolerant.

Eddie Johansson, Manager of Ena Energi, a biomass power station at Enköping in Sweden, told me there would be no problem in satisfying the requirements for food and bio fuel markets in the future; every minute, sufficient energy from the sun enters the earth’s atmosphere to satisfy our energy needs for a whole year. GM is an example of the technology we must embrace to enable us to capture this energy.

US corn production yieldtrend line

Bushels per acre



Source Pioneer Seeds

Yield increases and a reduction in costs of production are the obvious benefits of GM, but other gains, namely an increase in oil content of soya and rapeseed, increased starch in cereal grains or drought tolerance to enable more marginal land to be cropped. Japan has recently shifted its stance and now allows GM crops to be used for bio fuel production. I saw many crops of soya being sprayed with Round-up in Ukraine – Magic Soya beans..? The penetration rate of genetic crops is still low, but their increased use globally will be necessary to meet demands for agricultural produce.

“Magic” soya beans being sprayed with Round-up in Ukraine

12.2.1 Jatropha

Jatropha is a perennial tree shrub which produces non edible seeds that contain 30-40% oil, ideal for bio diesel production. One hectare of Jatropha can produce between 1.5 and 2 tonnes of seed oil. Since Jatropha are non edible and grown in marginal areas, producers can cultivate large areas that are not affected by rising food prices, require little water and do not compete with existing resources. A global market survey of oil crops by 'Bio diesel 2020' identified plans in India to plant up to 350,000 hectares and a total of 300,000 hectares in African countries: Mozambique, Malawi South Africa and Madagascar. Jatropha is not suitable for cultivation in the UK/Europe.

12.3 Algae for oil production

By absorbing carbon dioxide from the atmosphere and nitrates from water, marine or freshwater algae can double in mass several times in a day, producing 15 times more oil per hectare than alternatives such as rape, palm, soya or jatropha. (Table page 26). Shell has recently become involved in a project to grow marine algae at a pilot facility in Hawaii to produce vegetable oil for processing into bio diesel.

13. Bio fuels from waste

Skensk Vaxcraft is a centralised Biogas plant at Västerås in Sweden. The biogas company is owned by 17 local farmers, the local waste company,Vafabmiljo and the local municipality of Västerås. Biogas produced from the anaerobic digestion of 14,000 tonnes/year of organic household waste, 4,000 tonnes/year grease trap removal sludge (from the sewerage works) and 5,000 tonnes/year of ryegrass silage is upgraded, compressed and used as the fuel for the bus fleet in the city of Västerås.

The plant represented a total investment of £12.1 million; £6.27 million for the digestor; £2.59 million for gas storage, £1.02 million for pipe work and £0.02 million for satellite storage of gas at the bus station. The plant itself is 7 miles from the bus depot, and a filling station there is serviced by a gas pipeline.

Biogas from the plant contains 64% methane and 1000ppm of hydrogen sulphide and is saturated with water. The biogas upgrading operation is contracted out to the Finnish company YIT, working to a specification for cleaning gas. A re circulating water scrubber is used whereby the biogas is raised to a pressure of 10 bar before running through a water column, where the carbon dioxide dissolves in water and is removed. The upgraded gas contains 97% methane and less than 23mg of hydrogen sulphide per cubic metre. Gas is compressed to 330 bar for use in the buses.

Shareholding farmers are contracted to grow ryegrass, and are paid £0.02 /kg DM content for the ryegrass grown on set aside which receives no fertiliser applications, with 2 cuts being taken a year. The silage is stored at the biogas plant. The plant produces 22,500 tonnes of digestate slurry per annum. This is centrifuged and the liquid fraction is returned to farm via a contract with SITU waste company and stored in lined earth bank reservoirs on farm before spreading. The solid fraction is tipped on land and spread after harvest, much as sewage sludge is in the UK. The return of digestate to land completes the circle. Farmers pay for the digestate on a nutrient content basis, the digestate containing 5kg of nitrogen, 2 kg of potash and 1kg of phosphate per cubic metre. With current fertiliser prices this has a value of £3.30/cubic metre.

The regional bus company signed an agreement to use biogas at no extra costs to diesel and the fuel is paid for on energy content at an equivalent price for diesel. In February 2007 this was £0.59 /l. The capital costs of a biogas bus are 7-10% higher than the diesel equivalent, but since there is no tax on compressed bio methane as a fuel, the additional cost is quickly recovered.

13.1 UK potential

In the UK the government organisation 'Waste Resource Action Plan' estimates that there are approximately 20 million tonnes of food waste produced annually, if all parts of the food chain from the field to the kitchen are included. An average household will throw out 250kg of food waste every year! Historically this has been fed to pigs as swill, or disposed of in land fill. Land fill is no longer an option due to escalating land fill tax.

A Biogas bus filling up with compressed biogas at Västerås Bus Station

If all this waste could be collected and anaerobically digested, sufficient biogas could be produced to generate 650Mw of electricity, or one sixth the electricity generated by Drax power station. A report by the National Society for Clean Air and Environmental Protection entitled 'Biogas as a Road Transport Fuel' suggested the UK generates some 30 million dry tonnes of waste material a year, if animal and food wastes were included. This is capable of producing sufficient methane gas to meet 16% of road transport fuel demand.

Biogen Limited is leading the way with anaerobic digestion of food waste in the UK. At Milton Ernest near Bedford Twinwoods 1Mw biogas plant has been operational for over 18 months generating electricity from biogas produced from food waste and pig slurry. Biogen Ltd are establishing a network of plants around the country to digest food waste in this way.

In Sweden, I saw another good example of a waste material being combined with crops specifically grown for energy. At Enköping, the biomass power station, operated by Ena Energi, uses a mixture of willow short rotation coppice, sawdust, joinery waste and forestry thinnings as its feedstock. At Västerås with biogas and Enköping with biomass, the use of low or zero value wastes improves the financial viability of the plant. In some cases a "gate fee" can be charged for taking the waste.

14. Land coming into production

14.1 Ukraine

The former breadbasket of the Soviet Union, vast areas of black Chernozem soil capable of growing wheat, sunflower, rape, soya and maize, access to the black sea, paranoia about energy security, introduced by an over bearing neighbour who turned the gas pipelines off on the day of my Nuffield interview and a UK competitor for low cost production of bio fuel feed stocks were some of the reasons for visiting Ukraine.

Ukraine has come a long way since its independence in 1990. In May 2006 the exchange rate was 10 Hryvnya to the pound, a long way from record breaking inflation levels when the currency was introduced in 1996. Forget sterling here though, the "green back" is king in a country that references all trade to the US dollar. Heavy industry is prominent, but the country has the potential to be a serious agricultural power again with three quarters of the population of the UK in a country with two and a half times the land area.

Production of wheat along with all other agricultural commodities fell dramatically in the post communism years. In 1991, 21 million tonnes of wheat were produced; falling to 10.2 million tonnes in 2000. As the economic fortune of the country has improved, so has agricultural production with wheat production hitting 20.6 million tonnes in 2003. 2006 wheat production was 13.5 million tonnes, an indication of the influence of weather – winter kill of crops followed by drought reduced wheat production to 3.9 million tonnes in 2004. In 2006 the National Agricultural University of Kiev (NAAU) estimated that there were 6 million hectares of land not cropped.

(Figures NAAU).

I visited the NAAU at Kiev, and travelled down through the central part of Ukraine, through Cherkassy, Kryvi Rog, Kherson, Dneipepetrovsk to the black sea coast at Odessa visiting a number of farms and agribusiness on the way.

Foreign investment in agriculture is increasing, with German, American, and Dutch money encouraged by the security offered by long term land leases. Land cannot be owned by foreign nationals or companies. Ownership of former collective farms was passed to the people living and working on those farms in the early 1990s, each person receiving an equal land share. The 2001 Land Code of Ukraine formalized certificates and rights for land shares and made leasing arrangements of those land shares possible.

One such business I visited was managed by Scotsman, Peter Thompson who is taking on leases of land not previously cropped in the central part of Ukraine. Planned growth is to accumulate a total area of 200,000 hectares within 2 years. Between $40 and $50/ha rent was being paid for land. Rainfall in the central area of Ukraine is 350mm per annum, giving soya bean yields of 2 t/ha. Wheat and rape yields average 6.2 t/ha and 3.45 t/ha respectively. Sunflower and barley complete the rotation.

What of the prospects for bio fuels production in Ukraine, and export of cereals and oilseeds for processing else where?

There was much talk of a bio fuels industry in Ukraine but in May 2006 talk was all it was. Without legislation to mandate blending and domestic consumption bio fuels are seriously disadvantaged to fossil fuels with road diesel costing 3.6 Hryvnya/l (0.36p/l). Cropping trends reflect the market dynamics bio fuels have producing elsewhere. The area sown to winter rape jumped by an astonishing 73 percent from 2006, to 725,000 hectares for 2007 harvest. This marked the second consecutive year of substantial growth in Ukraine rapeseed area, driven by high demand for rapeseed in the European Union. (Figures NAAU).

With the diversity of oilseed crops that can be grown Ukraine will become a serious player in the production of feed stocks for bio fuel production. Logic would suggest production plants will be built in Ukraine, and the bio diesel exported into Europe rather than the oilseeds or vegetable oil.

Ukraine has secured good export markets for its cereals into North Africa. Freight rates of $35/tonne out of four main black sea ports, Odessa, Kherson, Mykolayiv and Mariupol giving an edge over wheat that has to cross the Atlantic from the US west coast for $65 -70/tonne. Bio ethanol production as a market for wheat will have to compete with this established trade; however, production levels are set to increase with better management and investment. If the Ukrainian producer can differentiate and produce high starch and low protein wheat, this will surely find its way into the bio ethanol production plants in Europe.

14.2 Russia

I saw a similar picture when I visited farms near Mitchurinsk in the Tambov area of Russia approximately 350km South East of Moscow, in May 2005. With only 20% of the farmable area under cultivation the rural head of the Oblast at Mitchurinsk was desperate for foreign investment to bring land back into production. The 2002 Land Code of Russia introduced new measures permitting the leasing of agricultural land to foreign owned entities within a statutory legal framework allowing land to be leased for a maximum period of 49 years. Recent analysis by the HGCA suggests 17 million hectares available for cropping in Russia.

Bringing land back into production in Russia

Michael Horsch, who I visited in Germany, confirmed the massive expansion into areas of farmland not cropped in Russia, Ukraine and Kazakhstan. On the day I spent with him at his factory at Scwhandorf in Bavaria, I met two brothers who were farming 78,000 hectares at Nizhny Novgorod, East of Moscow who had just purchased ten 18 metre air seeders from Horsch, spending £54 million on machinery.

Elsewhere in the world there is land that will come back into production to meet the new demand for agricultural produce. There were 3.8 million hectares of set aside land in Europe, of which 2.9 million hectares is estimated to come back into production in 2008. Credit Suisse predict that Brazil will be the sweet spot for global agricultural investment with over 100 million hectares of land available for cropping. In Africa and India, Jatropha could open up more cropping land.

15. Lessons to be learnt from successful bio fuel projects

In all the countries I visited there are a number of characteristics that defined successful projects; I define a successful project as one which is profitable, and has a sustainable and secure future:

15.1 Collaboration and cooperation

Whether it be collaboration between farmers in joint ownership of facilities; such as the many German and Austrian biogas plants; between farmers, the local authority, the local waste company, the local bus company in the case of Västerås biogas plant in Sweden; between bio fuels plants and local authority for export of heat energy into district heating networks; between farmers and private investors as is the case for many dry mill ethanol plants in the US, collaboration and cooperation are key ingredients in a successful bio fuels plant.

15.2 Farmer equity

With land and property assets, farm businesses generally have a strong balance sheet and are well placed to invest, or raise funds. Investment in bio fuels facilities, offer farmers the opportunity to take ownership of the next stage of a new supply chain, and in so doing take control of their own destiny. There is a vested interest for the plant to succeed by the party that supplies the raw materials. Farmer owned ethanol plants in the US place a requirement on the farmers to supply corn for the ethanol plant, offering security of feedstock. Supplies of this sort enable the plant to escape the vagaries of market fluctuation. This may mean that the farmer sells at less than the market price, but year on year a consistent price can be achieved. Finance for the farmer-owned Crystal Union ethanol plant at Bezancourt in France, were raised by retaining a proportion of the receipts for delivered sugar beet in one year. Of Austria's 1000 district heating networks in 2006, 660 were owned and run by farmers.

15.3 Security and availability of feedstock

A bio fuels plant that is not operational is a disaster, farmer equity and obligation of supply brings security. A lesson learned from Sweden, at Västerås Biogas plant, organic waste is the primary feedstock. Waste availability is variable, and to ensure supply of material for the plant grass silage is used, and ag bags of silage on site are available at all times. Similarly Enköping biomass power station primary feed stock is wood waste; sawmill and joinery off cuts and sawdust. Local farmers are however contracted to grow SRC to ensure that there is sufficient biomass available for the plant at all times.

Although it may seem obvious, having plentiful local supplies of feedstock material for use in a bio fuel plant is vital. Austria has 46% tree cover, which is mainly softwoods, so biomass figures strongly as a bio fuel.

15.4 Using waste materials and by products for bio fuel production

There are excellent examples in Sweden where waste materials are utilised and combined with energy crops to process waste and improve the profitability of biogas and biomass facilities.

Slurry is used widely in Germany as a base material for biogas plants, with maize added to improve gas production.

Utilising the heat energy produced in electricity generation

The financial viability of power generation and the efficiency is improved dramatically if the heat energy produced can be utilised. In Germany, Austria and Sweden district heating networks are in place to utilise heat from embedded generation. Selling heat for up to 0.27p/kWh gives another income stream to electricity generation.

15.5 Government support - subsidy, tax breaks and capital funding

Fossils fuels are subject to extraction and processing costs, but essentially fossilised carbon is available free of charge from the earth. Bio fuels are inherently disadvantaged and to stimulate development support from capital grants, tax breaks or subsidy is required.

In Austria, primary producers qualify for a higher capital grant rate for biomass infrastructure investment, 40% as opposed to outside investors who only qualify for 25%. This encourages vertical integration and recognises local sustainability keeping profits generated in the production cycle. Many US states have provided significant capital support for bio fuel plant investment.

It is wrong to say that we have no capital funding available in the UK; round four of the Bio energy Capital Grant scheme is due to be launched shortly, but it is a competitive process with many hoops and hurdles! Biogas plants could be eligible for funding under the new Rural Development Programme Funding, but with a plant costing £1.5 million how many projects could be supported? Our approach to supporting renewable energy is too complex and bureaucratic.

15.6 The planning process and regulation

US Bio Platte Valley ethanol plant in Nebraska went from conception to pumping ethanol and employing fifty local people in just over a year. Would that be possible in the UK.? I have just completed a Pollution Prevention control permit for a bio diesel plant which has taken the Environment Agency ten months to process and grant. I am not advocating that there should be exemption from the planning and regulatory process, but let's not stall efforts to get bio fuel plants up and running and slow the process.

15.7 Promotion

Promotion of bio fuels and their benefits is essential to raise awareness. In the US bio ethanol is promoted by the Ethanol Production and Information Council, a body funded by the ethanol producers. In 2007 the fuel used in Indi car racing was bio ethanol. Germany has the Fachverband Biogas EV which promotes the German biogas industry for power generation.

16 Opportunities for UK arable farmers

If the prices offered by contracts for growing wheat or oilseed rape for bio fuel feedstock are in line with the market price there is no reason why farmers should not grow for this market. I do not believe that this represents any particular opportunity however.

If there are future changes in duty on fuels and concessionary fuel for agriculture (red diesel) is no longer available it may be worth farmers investigating cold pressing rapeseed on farm to produce rape oil to use in modified tractor engines. Ironically this could be considered a return to the days when farmers produced fuel for their own consumption in the form of hay and oats for teams of horses. With rape prices where they stand at present cold pressed rape oil could be produced for 75p/l. If agricultural fuel was the same price as road diesel, the savings are marginal and an outlet for the rape meal would be required. Indirect benefits however could include reduction in carbon footprint of a farming business and energy independence.

Second generation bio fuel technology opens up a new range of opportunities. For the UK cereals are the crop covering the majority of land area. Three million tonnes of straw are returned to land every year. This straw could be used to make 600,000 tonnes of second generation bio diesel. Of more interest for farmers, could be small scale gasification plants used for CHP generation of electricity with heat energy used in new developments. This is a concept already well established in Denmark.

The most genuine opportunity I believe that exists for farmers in the UK is biogas. Biogas offers farmers the opportunity to become independent energy producers, producing electricity from a combination of waste materials (vegetable and food waste), animal slurries and crops specifically grown for energy such as maize silage. Using slurry and waste materials reduces the feedstock costs and improves the profitability. There are plentiful sources of these wastes available. Moreover, in terms of energy production per hectare, growing energy crops such as maize and converting the crop into methane through anaerobic digestion is one of the most efficient uses of land for energy production

Example UK 500kW biogas plant digesting vegetable waste and maize silage

Plant costs	£2,000,000
Electricity value (/kWh)	£0.130
Plant size (kW)	500
hours generating per day	24
Days generating per year	328
Hours generating per year	7872
Tonnes of maize silage required (158m³ gas/tonne)	5,000
Tonnes of vegetable waste (70m³ gas/tonne)	11,288
Cost per tonne maize (waste zero value)	£25
Total cost of maize silage	£125,000
Income per day	£1,560
kWh per year	3936000
Total income per year	£511,680
Bank repayments and interest	£140,435
Annual running costs	£85,000
Maize feedstock	£125,000
Profit before bank interest and repayments	**£301,680**

***Note**: Electricity value per kWh made up of ROC at double value 2 x £0.045 and electricity at £0.04 (contract price currently offered by Marks & Spencers)*

In 2009, the review of the RO will take effect and ROCs from biogas generation of electricity will be doubled in value. Maize silage valued at £25/tonne gives a gross margin equivalent to oilseed rape at £250/tonne and provides an additional break in the arable rotation. With a payback in 7 years, I outline a simple financial analysis above.

The by-product of anaerobic digestion is digestate, which with current fertiliser prices is a very valuable organic fertiliser. (See analysis of value below). In the future, technology for upgrading gas will improve and there will be opportunities to export gas into the grid; a higher value market than using gas to generate electricity will give potential for improved profitability.

Analysis of cost benefit of digestate as an inorganic fertiliser substitute

Inorganic fertiliser value per kg of nutrient				
	£/tonne	**% Nutrient**	**£/kg fertiliser**	**£/kg Nutrient**
Urea	220	46	0.220	0.478
Triple super phosphate	267	46	0.267	0.580
Muriate of potash	238	67	0.238	0.355
Umblicial application costs (contractor)		1.5	£/m^3	
Typical digestate analysis				
Nutrient	**kg/m^3 digestate**	**Value £/m^3**		
N	5	2.39		
P	0.5	0.29		
K	1.75	0.62		
TOTAL FERTILISER VALUE PER CUBIC METRE		**3.30**		
Net value of an application of	40 m^3/ha			
Note nutrient availability is as good if not better than in inorganic fertiliser (N 70%+ availability)				
Delivery of nutrients (40 m^3/ha)	**kg/ha nutrient**	**Value £/ha**		
N	200	£96		
P	20	£12		
K	70	£25		
Total value of nutrients delivered		**£132**		
Cost of application		£60		
Net benefit	**(£/ha)**	**£72**		

17. Recommendations

17.1 Recommendations to UK farmers

- Make the best of the increase in commodity prices as a result of first generation bio fuel production.
- Grow cereals and oilseeds for bio fuel production only if contract prices are in line with the market place.
- Invest in new energy supply chains, and become producers of energy from biogas supplying a local market for imbedded energy for new developments.
- Investigate the possibility of using straw to produce energy as technology develops.
- Consider producing fuel from rapeseed if concessionary fuel (red diesel) for agriculture disappears.

17.2 Recommendations to UK government

- Take a world lead on sustainable and ethical bio fuel policy.
- Make capital grant funding for second generation bio fuel technology available.
- Where cities are implementing congestion charging measures make vehicles running on bio fuels exempt from the charges.
- Allow concessionary road tax on bio fuel cars. (E85 and Bio methane cars).
- Consolidate the capital grants available for investment in bio fuels infrastructure into one programme and make higher rates available for primary producers.
- Through road tax and company car tax concessions encourage the use of bio fuels in captive vehicle fleets, particularly in situations where emissions and pollution are worse, for example buses and vehicles in cities.
- Review the restrictions on biotechnology for crops used exclusively for energy production.
- Decentralised generation of electricity is vital in the future with utilisation of heat from CHP essential to improve efficiency and financial viability. Retrofitting district heating into existing housing is uneconomic, so new developments must be built with district heating incorporated.
- Encourage the use of renewable heat from CHP for residential and industrial uses by extending the RO to cover heat, or raising tax on heating fuel.
- Put in place legislation and arrangements to allow bio methane to be exported into the Natural Gas Grid.
- Above all else avoid complexity and make all measures for encouraging bio fuels simple so as not to deter farmers and investors.

18. Conclusions

I outlined my aims and objectives at the start of this report some of which I have already covered, I summarise the other points in my conclusion.

Globally the production and use of bio fuels is being driven by energy security, the increasing costs of fossil fuels and search for alternatives and climate change. In the UK and Europe climate change is the main factor.

Bio fuels have an important role to play in a suite of energy technologies in the future, and are an important weapon in the armoury to reduce green house gas emissions. They are not a panacea; if the entire 2006 world cereal grain harvest of 1.57 billion tonnes was converted into ethanol in energy equivalent this would only supply 11 days of global energy requirement. Nuclear, coal, gas, oil, wind and hydro are also important. Despite escalating oil and other fossil fuel prices at present bio fuels are not economically competitive compared to equivalent fossil fuels and their use depends on Government legislation that mandates their use.

The rise in agricultural commodity prices that bio fuels have contributed to and oversupply of bio fuels has made production of first generation bio fuels with the exception of ethanol produced from sugar cane marginal. Ethanol is currently worth 23p/l, the cost of production of ethanol from wheat with current prices of £160/tonne is 34p/l. For some countries and feedstocks the increase in bio fuel prices has self limited their production. Using only first generation bio fuel technology substitution of fossil fuels beyond 10% will impinge on food production.

What impact will the production of bio fuels will have on food production and land use in the UK?

Much has unfolded in the last two years. There has been a massive increase in the price of all arable commodities and an associated improvement in arable farm profitability. The cost of food has responded to the increase in the price of agricultural commodities, with inflation on food running at 6%. Institutions and investors, such as Blackrock are looking to buy land and engage equity in practical farming. Schroders have set up an agricultural fund to trade in commodities and agribusiness.

Land prices have risen and to give an indication of by how much; a 4500 acre estate of grade 2 arable land that was sold in 2004 for £15.7 million has recently be sold for £32 million. Marian Fischer-Boel has responded to the increased demand and price increase for agricultural commodities by removing compulsory set aside in the European Community to increase supply for 2008 and stem the reduction in stocks of cereal grains. Agriculture has become part of the solution to the problems we face, as opposed to being part of the problem. Land values will reflect the fact that agricultural commodities, whether they be cereal grains, oilseeds or biomass, have a vital role to play in the production of energy as well as producing food.

Should farmers produce crops for bio fuel production? Yes and No.

Yes – Where it is possible to keep control of the whole energy chain and be an independent supplier of energy, growing the raw material, utilising waste materials and supplying electricity into grid and heat energy for developments.

No – Where the farmer is a commodity producer supplying bio fuel feedstock to produce bio ethanol and bio diesel at whatever price the buyer offers.

For the UK, domestic ethanol production will never compete with production from sugar cane in Brazil, with the physiological advantages of the crop and lower costs of production. In the UK, we have 60.78 million consumers on our doorstep with more interest in provenance of food than ever before, we should exploit this market first and foremost. Price improvements are a result of increased demand for agricultural products globally, bio fuels don't have to be produced at home just benefit from price improvements.

Will the world's population starve?

No - There will be unprecedented demand for agricultural commodities, however the world's population will not starve and the increased demand will be met through technology:
GM technology advances will enable plants to convert this energy into carbohydrate more efficiently in the future, we must embrace this technology. Second generation bio fuel technology will enable straw, corn stalks, rape meal and forest thinnings to be converted into bio fuels. Whilst second generation bio fuel technology develops Governments must implement sustainable and ethical bio fuels policies to encourage the industry to develop but not distort the balance between food and energy production. Energy will be produced from organic waste and agricultural waste and slurries supplemented with energy crops. Improvements in profits will bring land back into production and new crops will open up new areas for production.

When we eventually reverse the trend of greenhouse gas emissions and solve the problem of feeding a growing and more affluent population and also providing raw materials for energy production there will be another problem waiting for us.

Reinhard Koch, Manager of the European Centre for Renewable Energy, maintains that "a man who produces energy will be a wealthy man", judging by the wealth of some of the Arab states and their Sheikhs and Princes this is true!

On a personal level

When I applied for a Nuffield Scholarship I was uncertain about my future direction within the agricultural industry. I will always be indebted to the Nuffield Scholarships Farming Trust and my sponsors the Crown Estate for giving me the wonderful opportunity to study a new subject and broaden my horizons, helping me through a difficult transitional period in my career.

The experience has given me the stimulus and confidence to set up my own business and in January 2007 my company Greenerbridges Limited began trading. I now manage a number of farms for a Trust and also manage a farming business and property portfolio for a private landowner. The knowledge I have acquired through my Scholarship has enabled me to move into the area of Bio fuels and I now work on a number of Bio fuels projects, in particular for Biogen Limited helping develop a network of Biogas plants across the UK.

19. Glossary of terms

Bio butanol
An alcohol made from sugar or starch crops, which can be used as a petrol substitute. Has a lower vapour pressure, a more similar energy value to petrol, can be blended at higher levels without engine modifications than bio ethanol.

Bio diesel
A methyl ester diesel substitute made from vegetable oil, recycled cooking oil or tallow.

Bio ethanol
An alcohol made from sugar and starch crops, which can be used as a petrol substitute.

Bio gas
Combustable hydrocarbon gases, mainly methane, carbon dioxide and hydrogen suphide produced by the anaerobic digestion of any organic material; animal slurries, food waste, vegetable, green waste, crops and sewage.

Carbon abatement
Reduction or elimination of CO_2 pollution.

Carbon sequestration
The uptake and long term storage of carbon or carbon dioxide in forests, soils, or underground depleted oil and gas reservoirs, coal seems and saline aquifers.

CHP or Cogeneration
Combined heat and power, simultaneous generation of electrical and heat energy from the same source of fuel.

Emissions trading
Under the Kyoto Protocol allows countries to participate in trading of their allocated amounts of emissions enabling emission commitments to be met.

Field to wheel
Lifecycle GHG emissions including carbon storage of different land – use types, emissions from energy generation needed for irrigation, use of fertilisers and insecticides, planting and harvesting of crops, transportation to the bio fuel.

Fischer Tropsch Process
A reaction catalysed with iron and cobalt in which carbon monoxide and hydrogen are converted into synthetic fuels.

Gasification
A process that converts carbonaceous materials, such as coal, petroleum, petroleum coke or biomass, into carbon monoxide and hydrogen.

Global warming
Increase in the earths surface temperature.

Greenhouse gases GHG
Gases in the earths atmosphere that absorb and re emit infra red radiation, these gases occur naturally and through human influenced processes, Water vapour is the main GHG, and others include carbon dioxide, methane, nitrous oxide, ozone and CFC.

Greenhouse gas effect
Increased concentrations of greenhouse gases reducing outgoing solar radiation and increasing the temperature of the atmosphere.

Life cycle analysis
The environmental impact of a product during the entirety of its life cycle.

LEC Levy Exemption Certificates
Evidence of Climate Change levy exempt electricity supply generated from qualifying renewable sources.

ROC
Renewable obligation certificate.

Synthetic Bio diesel
Diesel produced by the Fischer Tropsch process from gases produced by gasification of any cellulosic material.

Syn gas
Gas containing hydrogen and carbon monoxide produced by the gasification process.

Well to wheel
Total GHG emissions of oil well during exploration, production, transportation, refining, storage, distribution, retailing fuelling and tailpipe emissions from the vehicle.