The Profitable use of Anaerobic Digestion (AD) on UK Farms



A 2005/06 Nuffield Farming Scholarship Study

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Contents

Executive summary	4	
Study objectives		4
The technology	4	
Travel	4	
Findings from the tours	4	
Application in the UK	5	
Introduction	6	
Background	7	
What is anaerobic digestion?	8	
Principle operations of a biogas to electricity plant		9
What is biogas?	9	
Uses of biogas	9	
Drivers for anaerobic digestion	10	
Environmental factors	12	
Benefits of biogas	1	12
Economics	1	13
Biogas	13	
Heat	13	
Digestate	:	14
Gate fees	:	14

Travel	14	
USA/Canada	14	
Key facts learnt from the US tour		15
Conclusions from the US tour	18	
Germany		18
Electrical power prices for biogas in Germany	19	
Anticipated German electricity from biomass production in 20	30 20	
Lessons learned from German visits	22	
Filling my knowledge gap, third tour	22	
USA	24	
PEFI alcohol process development and demonstration	25	
Lessons learned from 2 nd US tour		25
Applications in the UK	6	
Co-fermentation of energy crops	26	
Anaerobic digestion and waste treatment	29	
Economics of biogas production in the UK		29
The UK energy market	30	
Conclusions for UK agriculture	32	
Personal conclusions	33	
Stop press		33

Executive Summary

Study objectives

To understand the drivers that makes anaerobic digestion a worthwhile activity in other countries, to understand the UK framework, and to find out how to make the technology profitable under UK conditions.

The technology

Anaerobic digestion is an old well-established technology, extensively used in developing countries, principally in rural areas, with limited access to centralized power supplies. It is also well established in the UK as an integral part of sewage treatment works.

There have been attempts over the years to use the technology on UK farms with limited success. The technology relies on the use of bacteria similar to those found in the stomach of cows, these are kept in sealed tanks that are heated to specific temperatures, and then fed with a source of biomass, either muck or other matter. The bacteria digest the feedstock, breaking it down into a gas called biogas, which contains methane and a residue that is known as digestate. The biogas can be used for many purposes, but generally it is used for electricity generation on site; this can then be used on the farm or sold to the local electricity network.

The principal UK driver would be for electricity from renewable sources, for which a premium price is paid using a support scheme known as the Renewable Obligation Certificate scheme or ROCs.

<u>Travel</u>

Three separate tours were organized.

First to the Mid West of the US to see the technology in place on US farms and how they operated in a market that had no premiums for renewable power. Second was to Germany, home to nearly 3000 on farm units and growing by 500 plants per year. Thirdly, to the West of the US to see alternative uses for biogas to that of generation of electricity, principally the conversion of the gas to a liquid alcohol suitable for use as a road fuel.

Findings from the tours

The US has developed alternative markets for the digestate to complement the low price they receive for their electricity, these are principally based around the use of the digestate as bedding material for the cows when they are housed, which for most herds is all the year round.

The Germans have plans to turn biogas into a source of up to 12% of their national electrical needs by 2030. This has been driven by a favourable pricing structure; in addition they have turned anaerobic digestion into a biomass energy converter and moved from using the technology simply using manure and waste as a feed stock to using dedicated biomass, principally maize, grass and whole crop silage. This is the single biggest factor to affect the anaerobic digestion technology and its viability.

The US has different priorities and is aiming to reduce its dependence on imported fossil fuels for road transport use and is developing routes to convert biogas to a liquid alcohol suitable for vehicle use.

Application in the UK

Energy supply is becoming a higher priority and an increasing role has been outlined for renewable supplies, with new pricing frameworks about to be introduced. In addition there is a mandate that 20% of the nation's electricity will be supplied from renewable resources by 2020.

Biogas will have a place supplying renewable, carbon reducing electrical power, providing livestock farmers with an alternative income stream and also a means of reducing the pollution risk from their unit. Additionally, biogas offers arable farmers the opportunity of growing crops in an arable rotation and retaining the full value added benefits by carrying out the digestion process on the farm, or in the locality. A further issue that is rising in importance for western society is the issue of sustainable waste disposal. With sixty million people living in the United Kingdom, disposal of the organic waste is a major issue.

Anaerobic digestion offers a means of processing the waste into fertiliser and energy with the digestate being returned to land. This is likely to become a major role for UK farming in the near future. Of all the routes of transferring biomass into an energy form that is useful to society, I believe biogas offers a route that is efficient, is of a scale that is appropriate to farm businesses, and also has an appeal to farmers that other biomass crops such as miscanthus and short rotation coppice (SRC) do not.

The economics of biogas production from agricultural residues and energy crops under UK conditions are compelling in comparison to many agricultural investments. The changes to the renewable obligation certificate scheme currently under discussion are likely to provide sufficient incentive to farmers and investors to enter the market, and open the UK on farm biogas market.

The production of biogas from on farm units will not only mitigate methane gas emissions from livestock manures, it offers farmers a means of converting the crops they grow into a non food product, for example, a renewable energy that is required by a society that is keen to reduce the impact it has upon the environment, and this can only be supplied by units in close proximity to that society. Therefore competition for this service from overseas producers is unlikely, representing an exciting new opportunity to UK farmers.

The potential to process society's waste streams in a sustainable manner and returning the digestate to land is yet another service UK farmers will perform for society, and one that cannot be offered by farmers from overseas. This service will become a major role for UK agriculture in the future. The integration of waste disposal and energy crop production offers exciting future opportunities.

By constructing a unit on my own farm I hope to be at the forefront of this development, and provide the emerging UK biogas industry with a reference site to help demonstrate this opportunity.

Introduction

My study is to review the development of on farm anaerobic digestion in other countries and find a route that will enable anaerobic digestion to be profitable under UK conditions in 2005 and onwards.

The principal objective of my study is to understand the drivers that are allowing farmers on the continent and the US to build and profit from on-farm anaerobic digestion units on their farms, then fit these developments into a UK perspective. To do this I needed to understand both the economic and environmental frameworks in the countries selected for study and also how they differ from the UK

My interest in the topic was sparked when on a visit to the Agri-Tecnica show in Hanover Germany several years ago where one of the huge exhibition halls was full of stands devoted to biogas and its associated equipment. I had also noticed on the way through Germany, large numbers of wind turbines, both of these technologies were taking advantage of Germany's financial incentives to produce renewable energy.

The UK has introduced its own renewable energy enhancement system in the form of the Renewable Obligation Certificate (ROC) scheme and several electricity generation companies, and farmers have applied to build turbines with varying degrees of success. As a result of the opposition to on-shore wind farms, the UK is making slow progress to meet the obligations of 20% renewable energy by 2020 (currently 4.5%).

Observing the development of the wind turbine industry in the UK, I wondered if the conditions were not also suitable for the introduction of biogas plants in the UK.

As part of the Nuffield award, a tour of policy makers around Europe is a required element of the scholarship, and we were briefed upon forthcoming environmental legislation amongst others, and hearing of the increasing burden that will be placed on all farming activities, this information further confirmed that the time was right for an examination of the anaerobic digestion process and its place on UK livestock units.

Further moves to tighten NVZ restrictions also reinforced the potential benefits of an anaerobic digestion plant on livestock units. Any process that could add value to a costly waste product, make it more manageable and easier to handle would be a valuable tool for the livestock farmer to have. Recent increases in fertilizer costs have also emphasized the need to maximize the efficient use of manure.

The policy drivers in the UK for renewable energy have their origins in pollution control and the mitigation of carbon dioxide emissions into the atmosphere. For electricity production this comes in the form of the ROC and also more recently for road vehicles in the recently announced Renewable Transport Fuel Obligation (RTFO).

Within the intervening period from applying for my award, until writing this report, both the cost and availability of fossil fuels have come to be considered as an equally important reason for alternative energy supplies as pollution reduction. The whole issue of energy supplies and security has moved much higher up the political agenda and the increase in price of energy appears set to continue at the current higher levels. To reinforce the urgency of the UK situation, there has been a recently concluded Energy Review, which besides proposing that a new generation of nuclear power stations be built, has also suggested the market for renewable electricity be increased to 20% by 2020.

In the foreword to the Energy Review by the Prime Minister, there were the following quotes that are relevant to the production of electricity from biogas.

- Ensuring that we have a sustainable, secure and affordable energy supply is one of the principal duties of Government.
- The review also calls for more effort to encourage and support the local generation of power.
- We now face two immense challenges as a country energy security and climate change.

The tenor of these quotations, when taken in comparison to the government view on food security, indicates that energy security and climate change are seen as higher priorities than having a secure indigenous food supply.

There is also to be a review of the ROC scheme to encourage a wider range of renewable power supplies such as dedicated biomass including biogas and off-shore wind. The current scheme tends to encourage on-shore wind and landfill gas as the only renewable technologies that are viable under the current ROC system.

Background

Anaerobic digestion is a well-established technology and has been around for many years, with its application ranging from pollution mitigation at sewage works and fertilizer production, coupled with energy production as a primary or secondary benefit. It began to be used in the UK during the late 1800s as an integrated part of the Victorian sewage treatment programme and to provide street lighting. Since then it has continued to be used at sewage works and throughout industry as part of waste treatment processes.

In parallel to this throughout the developing world, anaerobic digestion has and is used as a primary source of cooking and heating gas in rural locations that remain isolated from the power and gas networks.



Small-scale plant, built inside a greenhouse type structure to raise gas production in colder months.

Over the years many enthusiasts have pursued the idea of on-farm biogas production either as a means of electricity generation or as a fuel for cars. Currently only a handful of on-farm digesters remain in operation on UK farms.

In my home county there is a redundant anaerobic digestion system at Piddletrenthide where Hanford Farms, a large pig farming operation, had been operating one successfully under the Non Fossil Fuel Obligation (NFFO). However the trough of the last prolonged pig cycle saw them exit from the pig industry and as a result the digester was shut down.

Moving up to current times, the most well known biogas business in agricultural circles in the UK is the centralised unit at Holsworthy in Devon. This plant is still in operation despite financial difficulties in recent years. To aid my report, an understanding of the reasons this plant has suffered financial difficulties would be necessary.

Financial problems with this unit I believe originate from the nature of its NFFO contract obligations to obtain 80% of its input energy from cattle manure, which is a dilute fuel source and because of its dilute nature cannot withstand the high transport costs that are incurred. The unit also uses other food waste as its co-feedstock. Whilst high in gas energy potential, it carries a high administrative cost and rigorous testing procedures are necessary to conform with animal by product waste regulations that followed the foot and mouth outbreak. When coupled with increased operational difficulty in handling these feedstocks, these costs largely offset the gate fees received, leaving a slim operating margin.

What is anaerobic digestion?

In the absence of oxygen, anaerobic bacteria will ferment biodegradable matter into methane and carbon dioxide, a mixture called biogas. Approximately 90% of the energy from the degraded biomass is retained in the form of methane; hence, very little excess sludge is produced. Biogas is formed solely through the activity of bacteria.

In evolutionary terms, anaerobic bacteria are very old, certainly much older than their aerobic counterparts. The anaerobic bacteria first appeared before oxygen was a major part of the atmosphere. This accounts for their inability to process lignin, as woody plants had not yet evolved. These bacteria were responsible for the production of the fossil natural gas that we use today.

The conditions that encourage this activity can be created artificially, and are carried out under controlled conditions, generally in sealed insulated concrete or steel heated tanks with some form of agitation. These tanks are known as anaerobic digesters.

There are two temperature ranges that best suit different strains of the bacteria, 30-35°c known as the mesospheric range, and 40-50°c known as the thermophilic range. These are the optimum temperature ranges to maintain the contents (substrate) of the tank.

The substrate remains in the tank for a period of days, known as the retention period (usually from between 8 - 50 days) depending upon the material being digested.

The mesophilic range tends to be easier to operate as the bacteria are more tolerant of temperature variations. This is the range that tends to be found in on farm digesters.

The thermophilic range is used when digesting material such as food or abattoir waste as the higher temperate involved destroy a higher percentage of pathogens in the feedstock. This has the benefit of requiring shorter retention times; however the process requires a higher degree of management and is generally considered less suited to the on-farm situation.



Principal operations of a biogas to electricity plant

During the retention period the substrate is separated into biogas and digestate

In agricultural terms, the digester can be thought of as similar to the stomach system of a bovine, as methogenic bacteria are responsible for the breakdown of the feed that cows ingest. As the bacteria are the same, the conditions inside a digester are similar to those in a cow's stomach.

Anaerobic digestion should be viewed as a means of unlocking the energy value that is contained in wet biomass material, in the same way as burning unlocks the energy value of dry biomass material.

What is biogas?

Biogas is formed principally from methane, typically 55% to 75% and carbon dioxide 45% to 25% with traces of nitrous oxide. Methane is the principal component in natural gas at around 95%.

Uses of biogas

Biogas in its raw state can be thought of as crude oil; it has limited uses and is saleable once it has been refined. It can however be used in certain boilers, and internal combustion (I/C) engines, although the contaminants in the gas can cause reliability issues, particularly in the case of I/C engines.

There are two types of upgrading process.

1. Light conditioning.

This reduces the levels of hydrogen sulphide (H_2S) in the gas and once this is done it can be used satisfactorily in I/C engines or micro turbines. The principal use of this type of fuel is for on-site electricity generation, as carried out at municipal waste dumps, landfill gas recovery, and sewage farms where sewage is treated to reduce odour and toxicity. The gas is then burnt in generators that produce power to help run the sewage works.

2. Full upgrading to natural gas standard.

This involves the removal of carbon dioxide, H_2S , and other minor contaminants. The combination of these increases the methane content to more than 95% (equivalent to natural gas). Once this is done all markets for natural gas become available, including use as a road fuel.

Drivers for anaerobic digestion

Before breaking down the drivers into separate headings I believe an overview of the methane situation is worthwhile and also extracts from a speech by UK agriculture Minister the RT Hon Ben Bradshaw at the launch of the International "Methane to Markets" grouping the aim of which is to reduce uncontrolled methane emissions from member countries. Worldwide methane emissions are responsible for 16% of the global green house effect.

A quote from the "Methane to Markets" website home page says -

"The agriculture sector is responsible for over fifty percent of human-related methane emissions worldwide and global trends towards more concentrated and commercialized livestock operations will provide increasing opportunities for methane recovery and utilization from livestock waste management"

I believe it is also worthwhile copying the following speech:

Ben Bradshaw MP - Speech at the launch of the 'Methane to Markets Partnership', Washington, US, Tuesday, 16 November 2004 -

"I would first of all like to take this opportunity to thank our American hosts for the considerable effort and resources they have committed to establish and launch this important and timely Partnership."

"As our Prime Minister, Tony Blair, made very clear recently, we consider that climate change is the greatest environmental challenge facing the world today. Global warming is already occurring at an alarming rate and there is no doubt that the time to act is now if we are to avert disaster in the long term. If we do not then the impacts will be far-reaching and irreversible in their destructive power. That is why we have announced that addressing Climate Change will be a top priority for our G8 Presidency next year."

"Whilst it is, of course, right that much of our attention will focus on reducing emissions of carbon dioxide, we are very aware that methane is also a very significant greenhouse gas. And that is why the UK very much welcomes the launch of this Partnership with its aim of recovering and utilizing that methane for energy. Climate Change cannot be resolved by any

one-nation acting alone. It does not respect frontiers and only international action commonly agreed and commonly followed through can make a difference. We hope this Partnership will act as a shining example of what that international co-operation on individual issues and technologies can deliver, to support international action under the UN Framework Convention."

"In the UK, we have already had considerable success in reducing our methane emissions, which fell by nearly 43% between 1990 and 2002 with substantial falls in emissions from landfills, coalmines and oil and gas production. This will be a significant contribution to meeting our emission reduction commitments under the newly ratified Kyoto Protocol."

"Recovery of methane for energy use has been a key part of that success and today landfill gas accounts for around a third of the UK's output of renewable energy. We have used a range of technical, policy and regulatory levers to achieve these successes. This includes covering methane under our domestic emissions trading scheme, which has provided us with very helpful experience ahead of its possible inclusion in the EU emissions trading scheme from 2008."

"Nevertheless, we recognize that we still have much to learn and look forward to using the Partnership to share our experiences and also learn and profit from others. We believe it is particularly important that we focus as much on the markets as the methane and recognize the enormous potential here for innovation, for scientific discovery and hence, of course, for business investment and growth. As with other non-conventional energy sources, we need to ensure that the markets we have created to maximize efficiency do not penalize our attempts to create diversified sources. With the right framework for action we can help provide jobs, technology spin-offs and new business opportunities whilst helping to protect the world we live in. We are therefore pleased to see the inclusive nature of the Partnership with its clear commitment to co-operate with the private sector, banks and other players to deliver effective policy frameworks to support private sector investment."

"As a Minister from a Department that includes Agriculture under its portfolio, I also believe that it is important that the Partnership turn its attention as soon as practical to the potential to control, recover and use methane emissions from the agricultural sector. This is a sector that is responsible for a very significant proportion of methane emissions across the globe and where we must be looking to increase emission reduction rates if we are serious about tackling climate change right across our economies."

"Finally, I would like to re-iterate our commitment to making a success of this Partnership and we are now looking forward to working with our Partners to ensure that the momentum generated by this successful launch now starts to generate real progress on this key issue. With Kyoto now on the verge of entering into force, courtesy of President Putin's Russia, and oil prices reaching new highs there has never been a better time to advance the recovery and use of methane as an alternative, clean energy source and so never a better time to launch this new Partnership."

That speech was made just prior to my applying for my Scholarship, I believe it gives a good overview of the problem of uncontrolled emissions, alludes at the potential for business opportunities in the control of methane, but also hints at the attention that is about to be turned on agriculture with regard to this issue.

Environmental factors

One of the principal drivers or advantages of anaerobic digestion is its ability to turn organic matter into a usable energy form. It also aids the reduction of uncontrolled methane emissions into the atmosphere. The reason these uncontrolled emissions are undesirable is that methane is a greenhouse gas twenty one times as damaging as a CO_2 .

When vehicle fuels are burnt they produce water and carbon dioxide. Renewable natural gas has all the advantages of low emissions as natural gas, but with the added advantage that the carbon dioxide produced, is renewable carbon dioxide. It is not the same as that of fossil fuel, as the carbon in the exhaust has come from the carbon dioxide recently taken from the air by vegetation during its growth cycle.

Biogas is part of a natural cycle, and as such, benefits from incentives for renewable energy giving biogas a comparative advantage in the marketplace.

Benefits of biogas

Compared with petrol or diesel, the benefits of vehicles fuelled by fossil natural gas include:

- Considerably reduced exhaust noise levels
- Lower emissions of nitrogen oxides
- Almost zero emissions of particles or dust

Besides all the above advantages, renewable natural gas (biogas) offers additional benefits:

- No net contribution to the greenhouse effect
- A renewable source of energy
- Locally produced without any dependency on foreign oil or natural gas suppliers
- Provides a closed loop energy system

The above benefits have been outlined for the use of renewable natural gas as a road fuel, however the same principals hold true when the gas is used as a fuel for electricity generation when it is displacing other fossil fuels.

A recent report from the National Society for Clean Air and Environmental Protection (NSCA) has concluded that one tonne of organic waste used as a vehicle fuel would reduce carbon emissions over fossil road fuel by 413kg, and if the same tonne were used for electricity production it would reduce CO_2 by 529 kg over its fossil equivalent.

Diagram of the biogas life cycle



Economics

The output from a biogas plant is twofold, biogas and digestate, both of which have a value. A third potential income stream is from gate fees for organic waste material that could be used as a feedstock.

Biogas

Biogas has a calorific value that can be directly compared to any other energy carrying form such as oil, coal or natural gas, however by its renewable nature the gas has the ability to attract any renewable energy premiums that are available.

If the gas is used to turn the energy into electricity on site then heat is also produced and potentially has a use and value. Biogas is typically 50 to 70% methane by content with the balance being CO_2 . Biogas is chemically the same as natural gas but is of lower calorific value; it should be thought of as "crude" or unrefined natural gas.

Currently in the UK, the most profitable and easily accessed market for biogas is undoubtedly the electricity market. Electricity produced from biogas benefits from the Renewable Obligation Certificate (ROC). This is currently valued at $\pm 33-\pm 48$ per megawatt hour which is received in addition to the price received for the power itself, and can represent around 50% of the total revenue stream for the electricity. This is the principal economic driver for a biogas plant.

As biogas is such a flexible fuel, many other uses are possible in the future

<u>Heat</u>

When generating electricity, heat is produced as a by product. This tends to be in the form of low grade heat, around 90°C, which is ideal for heating of houses etc.

A well-placed biogas plant can sell its heat to many different consumers or indeed an additional enterprise, activities such as biomass drying or horticulture could be placed adjacent to a biogas plant.

Digestate

The process produces digestate as a co-product of the digestion process. The bacteria work on the volatile organic solids that are in the substrate. Generally these compose around 5% of the feedstock and are destroyed during the process, so as a rule of thumb; the digestate equals 85 to 95% of the feedstock by volume.

Due to only the organics being destroyed, the mineral fertiliser value is completely retained within the digestate. The bacterial action also has the effect of mineralizing some of the volatile nitrogen thereby increasing the quantity made available to a following crop.

The action of digestion also unlocks other nutrients held in the digestate. This increases the quantity and value of any application to the following crop and subsequently reducing potential for run off.

Gate fees

Gate fees can form a large element of an income stream for a biogas plant. With the increase in landfill tax now on an escalator basis, further controls on routes of disposal being closed off for organic waste streams. The potential to earn gate fees from waste streams is an important potential area of income to a biogas plant developer.

The category of waste the feedstock is categorized as, dictates the likely size of the gate fee and also the regulatory burden that needs to be complied with, which can also have substantial cost implications.

<u>Travel</u>

As I have outlined in my introduction, I wished to visit Germany where the anaerobic digestion or biogas market seemed well established. Research on the internet also revealed considerable work being undertaken with on-farm anaerobic digesters within the US.

As a Director of Wessex Grain and Green Spirit Fuels, both operating in the grain to ethanol sector, I also wanted to include a visit to the Fuel Ethanol Workshop. This is an annual event for all things relating the bio-ethanol, so a trip that took in both technologies was a must.

I had two trips pre planned and I felt I would leave any further travel arrangements open until after these and then undertake further travel once I had assimilated what I had learned on the first two trips.

One other reason for visiting the US was that farms that had a digester would tend to be larger dairy units and I would get a chance to visit these units, meet with the operators and gain an insight into large diary unit management, US style.

<u>USA/Canada - Saskatchewan, Minnesota, Wisconsin, Kansas, Missouri, South Dakota, New York, Connecticut</u>

My first tour took me to the USA, where I travelled briefly to Canada to visit the Farm Progress Show in Regina, Saskatchewan, back to Minneapolis, and then to Wisconsin to a renewable energy fair, various farm and digester visits, including the opening ceremony of the Elk Mound Digester. This was a Danish designed plant that was utilising manure from nine hundred cows and other feed stocks.



Farmers Lee and Jim Jenson and Jims wife Jean Amundson, cut the tape at the opening ceremony for their five star dairy, Elk Mound Wisconsin Anaerobic Digester

The Microgy Thermophic Anaerobic Digester unit at Elk Mound

The digester is in the background and 775 kWh Waukesha engine driven generator in the foreground

I then travelled on to Kansas City to the 2005 Fuel Ethanol Workshop, up to South Dakota to visit the site of Prime Industries proposed combined ethanol, anaerobic digester and feedlot project also one of only two on-farm ethanol plants operating in the USA. Then back into Minnesota to visit the University and the biogas to fuel cell project and other on-farm digesters.

Throughout the trip I intended to visit any ethanol plant I happened to pass, however after the first four, I was able to resist the temptation to stop and visit. Whenever I did stop, I was always received with courtesy and interest, and continue contacts with many of the people who I visited.

A flight back to New York and further on farm visits in New York State and Connecticut, a total of 5,500 driving miles before returning to the UK.

Key facts learnt from the US tour

One of my main reasons for visiting the US was to see how on-farm digesters were financed. Considering the fact that there are virtually no premiums for renewable power in the US, I was also keen to discover construction and other costs, to see if there were any cost savings from the fact that they were operating in an unsubsidized electricity market.

In conversation with owners it soon became apparent that for them it was a number of factors that were combining to make the projects feasible. One main concern was pollution mitigation, odour being one of the main problems. Despite the perception from this side of the pond, that the Americans have little if any problems with environmental matters, this is certainly not the case. They have to be aware of their neighbours just as we do, and the Environmental Protection Agency (EPA) is keeping a close watch on ground water pollution, with phosphate being their greatest concern.

The factors involved with both of these issues tend to be aggravated by the concentration of a large number of animals on one site. Most dairies I visited had at least eight hundred milking cows and many were looking to expand (generally doubling in size). The installation of a digester helped to overcome neighbours objections to consents that were needed for the expansion. A second factor is the higher awareness in the industry of the benefits in the field of pollution mitigation that digesters bring. I believe that this is mainly due to both State and Federal funded research programmes. Whilst the practitioners complain of budget cuts, to me it was like stepping back twenty-five years to the time that we in the UK had such facilities and support. It was refreshing to see such interest in agriculture from public bodies.

The principal Federal Grant Scheme is named the Agstar Program. This offers access to capital grants, interest free loans, and all kinds of technical support to farmers considering installing a digester. In addition to the environmental benefits that were a key factor in digester installations, the Americans were still keen to make the investment pay, and to this end they were showing great ingenuity in creating revenue streams from all outputs from the digester. With little or no environmental premium for renewable power and a cheap power economy, the best payment rate for the electricity produced was around 7 cents per kWh (3.78 pence). This would provide around 50% of what would be needed to make the unit viable.

Replacing the electricity purchased at a higher rate contributed some benefits, and with long periods of freezing temperatures during winter months, savings on purchased natural gas for heating also contribute. However the major development has been the use of the digestate as a source of material for bedding material. The digestate is put through a solids separator and the dry material is then used as bedding in the farm's cubicles. As most US dairy farms rely on bought in food and bedding, this reduces their expenditure on this input.



Cows at Elk Mound Dairy, Wisconsin bedded on dried digestate

In addition to this there is widespread sale of this product to neighbouring dairy units.

Others had been more creative in their marketing and had moved into to sales as garden compost.

The University of Wisconsin was doing considerable work in finding the most appropriate use of the digestate fibre as a moss peat replacer.

Matt Freund in Caanan, Connecticut, had been working on his alternative uses for the fibre for several years and had developed a range of disposable plant pots that were bio-degradable and also acted as plant fertiliser/soil conditioner as they decomposed. He was also working on the use as a biodegradable mulch material; once again to replace the conventional plastic in current use. He had received federal funding for much of his development; however he was still a little way from commercial launch.

Prof. Phil Goodrich from University of Minnesota is conducting a study at the well known Haubenschild Digester in the conversion of biogas for use in a fuel cell. This was a fascinating glimpse into the future as to how flexible the gas is, and is likely to play a role if and when fuel cells ever come to fruition as energy converters.

For me the most imaginary and innovative project involving biogas was at Pierre, South Dakota, where I met Phil Lusk, an economist well known in anaerobic digestion circles in the US and a key figure in the South Dakota Value Capture Co-op. This project involved the integration of an ethanol plant that produced ethanol and brewers grains. The brewers grains would be fed to an onsite feed lot, where beef would be sold, the manure from the beef cattle would then act as feedstock for an anaerobic digestion plant that would produce gas to power the ethanol plant and produce fertiliser that would grow the crops that feed the ethanol plant. By its method of operation, the project became closed loop, with the output from each process contributing to the next process. By its nature this system would have a fantastic energy balance and would revolutionise the rural economies of the mid western States.

Unfortunately due to restrictions as to who can own cattle in South Dakota (a measure to protect farmers from corporate business interests) the financing of the project has yet to be completed, however the model has been copied and several other existing ethanol plants are now using this model as their energy source. With natural gas becoming more expensive, this way of powering ethanol plants is becoming very attractive.



Artist's rendition of a "closed loop" facility consisting of an ethanol plant, a partially enclosed feedlot and an anaerobic digestion system. To be built by the DVCC in Sully County.

Conclusions from US tour

- Biogas plants are a good pollution control measure.
- American anaerobic digester designs were simple and robust, yet issues still existed with regard to general construction, including gas leakage and in particular engine reliability, with high maintenance costs and low operating percentage.
- Micro turbines can be used as an alternative to I/C engines; however they required more gas conditioning and as yet were not suited to on-farm use.
- Retain the option to access the digester vessel for clean out, as solids will collect and need to be cleared.
- To ensure economic viability, all revenue streams needed to be maximised.
- A digester needs to be given regular attention, in the same way as a livestock enterprise does.
- The most significant thing I saw was that the American "Can do" attitude at work and several examples of incredible enterprise and determination with little sign of waiting for policy to enable developments. Private business was creating opportunities, whilst this would never unlock the full potential of the technology there were good business opportunities in specialised niche applications.

<u>Germany</u>

During the winter of 2005/6 I undertook a total of three visits to Germany to establish and follow up with contacts within the Biogas industry there.

Over the winter/early spring I made another three visits to Germany. First, to the Agri-Technica show in Hanover. There were many companies exhibiting, with whom I made contact to arrange future visits. Whilst contacts were made, follow up contact proved difficult.

To progress the study I visited Hanover again to attend the tenth German biogas association annual convention. This was a three-day convention and trade fair with seminars throughout the three days. It was a good insight into how advanced the German biogas scene is. A far cry from the inspired low-tech nature of the scene in the US, which in its turn is advanced over anything that we have here in the UK.

The convention was principally aimed at owners, potential owners and operators of plants. Seminar topics included areas of new development, safety, and public relations. The event was a great experience and I was able to gain a good insight into all aspects of the German biogas industry. It was here that I began to understand why earlier approaches were slow in eliciting responses.

Due to the massive growth in the industry and a boom in the construction of plants in Germany, the manufacturers have long waiting lists for their plants and can hardly keep pace with German demand. As such, they are fully committed to the booming biogas market within their own border, although there were some companies taking a longer term view and willing to talk with foreign parties. Here I made many good contacts, and many friends, and was able to put together a good collection of contacts for a future tour to view on-farm digesters.



The single biggest factor that I have discovered during my studies is the co-fermentation of energy crops with manure in digesters. This has transformed the anaerobic digestion industry in both Germany and Austria where co-fermentation is now the major driver for anaerobic digestion plants. In this context energy crops are not miscanthus, willow or short rotation coppice (SRC) but maize, grass, whole-crop cereal, basically any green matter.

To encourage this development, the German electricity feed in tariff system operates on a variable pricing structure to reflect the costs of different sized generating units and substrates. This can be seen from the following table. Biogas plants fed with energy crops receive an additional 6 Euro cents per kWh generated.

Average Power	Guaranteed fixed Basic Price i.e. using waste	price €Ct/kWh Bonus for agricultural plants using just manure, energy crops	Bonus for heat usage
0-150 kW	11,5	+6	+2
150-500 kW	9,9	+6	+2
500-5000kW	8,9	+4	+2
>5000kW	8,4	+4	+2

Electrical power prices for biogas in Germany

Whilst these rates are high, the Germans have a view on where they wish their power to come from. They are resisting further nuclear developments and they are nervous about being dependent upon Russia for over 75% of their natural gas requirements.

The following diagram shows what they hope to achieve by 2030.

Bioenergie: Was kann sie im Jahr 2030 leisten? 100% Gesant-Deutschlang Bioenergie: Was kann sie im Jahr 2030 leisten? 17,4 So Bioenergie: Was kann sie im Jahr 2030 leisten? 17,4 So Bioenergie: Was kann sie im Jahr 2030 leisten?

Anticipated German electricity from biomass production in 2030



Following my time at the biogas conference, I made plans for a trip to Germany to visit farms and manufacturers to establish the practical aspects of the German biogas boom.

I had developed particularly good relations with a company called Biogas Nord of Bielefeld and through their good offices, spent a week touring farms, research institutes and manufacturers involved in the biogas industry. As I toured the various farms with Reinhold Poir of Biogas Nord, I quickly noted a marked difference from my trip to America. In all but one case, the generator was running. In the US, 75% of the generators weren't running at the time of my visit.

I visited a full range of units from one on an organic dairy farm that had been installed for several years, to a huge facility on the outskirts of Paderborn/Lippstadt airport. This unit was partially built and was powered by pig manure and various food wastes, including waste chocolate imported from Holland. Not only was this unit generating an income from the electricity and gate fees for handling the organic waste, the waste heat from the I/C engine was supplying the heat for the airport terminal building and also a hotel that was under construction at the airport.

As I discovered more about the German situation, it was obvious that they had been thorough in their development. None of the problems that plagued the Americans were evident and the two big issues in the US of gas sealing of the digesters and hydrogen sulphide removal from the gas had been achieved with simple elegance. Not only was the technology far more advanced, but also due to economies of scale and production numbers, the costs were broadly in line with American installations.

On my various trips, I met the farmers operating the plants and gained a good understanding of the economics of running the plant and of growing the energy crops.



Herr Oberkrome Tasche Farm and biogas plant: Note the unit fits unobtrusively into the landscape.



English – German farmers in discussion, in English of course!

As can be seen by Herr Oberkrome-Tasche's smile, he is pleased with his biogas plant, and is looking to double its output shortly. Note the tanker for digestate spreading in the background.

Further visits included spending some time with 2G Engineering at Heek, just inside the German border from Holland, where I furthered my knowledge on the various aspects of the combined heat and power (CHP) units that generate the electricity.

My time in Germany had given me a great insight into how, once a policy was put into place, industry and farmers react rapidly to it, and whilst the price for the electricity offered seems high, it has many spin off benefits besides increasing the amount of power being generated by renewable biomass, the chief one being the construction of an indigenous power industry. This is now not only serving Germany, but as the rest of the world looks to biogas as a fuel source, it is German expertise that leads the field and is creating export business for German industry. There are now over 150 different companies involved in the biogas industry in Germany.

Lessons learned from German visits

Co-fermentation of energy crops has transformed the biogas industry.

German designers have refined the construction process to production line standard.

Packaged units are available that have full support and process guarantees, this raises the generator running time percentage from an industry average of 65% to over 90%.

There is an Industry body, The German Biogas Association that fosters a professional outlook. The Industry has reached critical mass and now funds research into efficiency increases. Prioritising the biogas plant is important and should be considered in the same way as a livestock enterprise would be.

Filling my knowledge gap - third tour

Following my visit to Germany, I now had a good overview of the biogas to electricity market and had seen the way forward for that sector in the UK. Through my involvement in the bio-ethanol market I am aware that for the ethanol industry, one of the "Holy Grails" is for "Ligno-Celulocic" fermentation, for instance, the use of the whole plant matter rather than just the grain or starch element of the plant. This would have the effect of increasing the energy efficiency of the bio-ethanol industry and not only would this disarm the leading criticism of biofuels perceived poor energy balance, but it would potentially give greater ethanol yields from a given area of crops, having now seen and understood the concept of using energy crops and biological fermentation as a route to unlocking the energy value in crops.

I wished to investigate further the conversion of biogas to a liquid fuel, as an alternative market for biogas, and as an alternative to the existing starch to ethanol method.

The following chart produced in a report for the DTI shows the relative energy balance for a range of crops for bio-energy production. What we can see is that for crops that use the whole plant as a feed stock, for example, maize and grass, the energy yield and balance are greater.

	Product	Input	<u>Output</u>	Balance	<u>Ratio</u>
W Wheat	Bio- ethanol	26.47	61.14	34.67	2.30 -1
W OSR	Bio- diesel	22.00	40.25	18.25	1.83 -1
W. Wheat	Bio-gas	22.00	101.39	68.48	3.11 -1
Maize	Bio-gas	32.4	190.0	157.6	5.24 -1
Rye-Grass	Bio-gas	30.18	131.8	101.62	4.35-1

Energy balance (GJ/Ha/Yr)

In my research to this topic it became apparent that Sweden is fast developing the biogas to road fuel route. They are well advanced in the use of biogas production from various feedstock streams and from food waste to energy crops, however as they have a well developed hydro and timber fuel electrical power supply, the conversion of biogas into electricity was not attractive to them. Unlike their neighbour Norway, they have little natural gas or other fossil fuel reserves. Couple this with a progressive outlook towards climate change; the Swedish government have set policies in place to encourage renewable transport fuels with the aim of being free of fossil fuels by 2020. This is likely to be made up from a mixture of fuels from ethanol, bio-diesel and biogas; indeed the Swedish car market has already reached 50% market penetration for flex fuel or dual fuel cars.

Flex fuel cars can utilize either of two liquid fuels, in any combination, for instance fossil petrol or bioethanol, or dual fuel cars that use either liquid or gas, as Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG).

So from the Swedish experience there are many delegations and subsequent reports on the technology, so I felt I could gain as much from collating my requirements from existing work as I could from making the visit myself, and my resources would be better utilized looking elsewhere.

My earlier tour of the US had shown that for the Americans, the road fuel market is a major national concern. The recent rises in fuel costs (although still far lower than those in the UK due to lower fuel tax) and concerns about fuel security are driving both Government and private research into additional sources of fuel.

I also felt that the British political view in the fuel arena was more akin to the US than it was towards Sweden, in that we were among the last in Europe to adopt a policy to include a mandatory level of renewable fuels into the fuel supply. I also can't see the political will to assist in setting up a parallel distribution system such as would be required for a biogas to transport fuel model, as per Sweden would be required. Without this, the use of gas as a transport fuel in the UK will remain a niche fuel only.

I wished to explore avenues for markets other than on-site electricity generation and felt that the US would be the place to visit once again.

There is an interesting point that should be made here with regard to the energy balance debate for all biofuels. It is that as fossil fuels are now established as the principal transport fuel and the infrastructure is built around them, all other fuels have to be adapted to fit into this system, and this often takes energy in the conversion process.

As an example, ethanol has to be completely free from moisture to blend with fossil petrol. During distillation the alcohol produced would typically be 85-90% ethanol and the balance water. Engines can, and do run on this mixture happily; indeed water injection is used in both aviation and in racing cars to raise engine performance. However, as water and petrol do not mix, this water has to be removed at a considerable cost in energy consumption at the ethanol plant.

If this energy cost is the price paid to access an existing system then it is justified, however the biofuel industry should not have the energy balance argument used against it when very often energy is used to make the fuel compatible to existing stocks and to save the consumer from the inconvenience and cost associated with an alternative fuel supply such as equipping a car with a dual fuel kit.

The situation regarding liquefied petroleum gas (LPG) is a good example in that despite having considerable duty exemptions, the additional cost of vehicle conversions and the difficulty in finding filling stations has kept public participation at extremely low levels.

In this context, I wonder how many of us know the energy balance of oil or natural gas? No doubt it will vary depending upon the location of the respective fields, however the energy consumption used in extracting and refining of these fuels is considerable, particularly when it is becoming more common, the fields are found at increasingly remote locations around the world. I know that in the case of natural gas; where a pipeline cannot be laid, and the gas has to be compressed and shipped as liquefied natural gas this process can use up to 25% of the energy value.

USA - Colorado, Utah, Wyoming

For this tour I made arrangements to visit both national and private research companies and also farming businesses involved in various projects.

First stop was to south west Utah to see Smithfield's foods, that had announced a \$20 million plan to make bio-methanol for use in biodiesel from biogas made from the manure from their 60 farms spread over a 30 mile radius in southern Utah.

This huge business is the worlds largest pig operation and the circle farms that would supply the proposed muck to methanol plant being the 15th largest pig operation in the US. The project would solve two issues, pollution mitigation, and rising fuel costs.

This is focusing the company on the energy value in the manure that their pigs produce. They have access to technology that will transform the biogas to methanol, which will then be used in the production of biodiesel. However, they had yet to form the necessary partnerships to progress the biodiesel plant, so the project is still as yet on the drawing board.

At Salt Lake City I visited another on-farm digester; this again was an innovative development project producing gas from 1200 cows. Details of its method of operation were guarded, one fact that was hard to hide was that the generator was broken down, yet another victim of gas contamination, an issue that so far seems to be low on the list of priorities within the US, despite its cost in terms of increased maintenance to the generator power unit and lost output.

Following this stop I travelled across Wyoming to Laramie where I had an appointment with Dr Vijay Sethi to discuss his work on bio refining gas to liquid fuel and also thermal combustion of biomass. Of principal interest to me was the work on the conversion of gas to an alcohol fuel. There are several strands of work on going, most of it still at bench test level which I was able to see and some was about to reach the pilot plant stage.

PEFI Alcohol process development and demonstration

<u>Power Energy Fuels Inc. (PEFI)</u> is a Colorado-based corporation that has a licensing agreement with PowerEnerCat Inc. (PECI) for the use of a patent-pending catalyst (EcaleneTM) that can convert any carbon-based material into mixed alcohols.

EcaleneTM can be marketed as an alternative motor vehicle fuel to be sold as either a 100% alcohol fuel or a 10% + blend with gasoline to provide a cleaner burning automotive fuel.

Composition of Ecalene		
Component Weight. %		
Methanol	0%	
Ethanol	75%	
Propanol	9%	
Butanol	7%	
Pentanol	5%	
Hexanol & Higher	4%	

Feed stocks suitable for use with the PEFI process include:

- Landfill gas and digester gas
- Municipal solid waste or befouls
- Natural gas from pipelines or shut-in wells
- Coal and any other carbonaceous material

I then travelled to Golden Colorado, to the US National Renewable Energy laboratory where I met the team involved in alternative fuels. Fuel supply again was the key concern rather than carbon mitigation and the environmental issue which lie behind the drive to renewable fuels in the UK.

The calculations in the US are that crops such a switch grass, grown on land used to grow crops for export, land taken out of production under their Conservation Reserve Programme (CRP) and other range land could theoretically provide up to 75% of the US road fuel requirement!

Lessons learned from 2nd US tour

Despite low duty incentives to use renewable fuels, the issue of fuel security is at the top of the USA's priority list and alternative fuels are, and will be, big business with lots of opportunities.

Research being undertaken for and on behalf of other industry sectors in the energy field can be transferred to the renewable biogas sector, as biogas is chemically identical to natural gas. Indeed biogas is the only renewable energy form that can exactly replicate its fossil equivalent; therefore it can be used in all natural gas applications.

Gas to liquid fuel is very near to commercial market reality and will give a valuable alternative market for biogas producers.

Applications in the UK

Biomass is often talked about as an option for farmers to access the energy market. There are two principal methods of releasing the energy locked up in energy crops: biological gasification, by bacteria in anaerobic digesters and thermal gasification of higher dry matter crops such as miscanthus and SRC. It is generally this method that comes to mind when biomass is spoken of as a method of energy production.

The move into these crops is a large step for farmers to make. Once the decision is made to plant these crops, the land is committed for a period of several years and the farmers' options and alternatives are limited, additionally SRC can be damaging to land drainage systems. The uncertainty over the building and successful operation of a plant to process these crops causes the classic chicken and egg situation, with each party looking for the other to make the first move.

The gasification process is technically well understood, yet there are relatively few companies producing the technology that can give the required guarantees for the reliable operation required. As a result, the area planted to these crops of 4,700 ha indicates that farmers are indeed reluctant to commit their land for this purpose. The exception to this is where farms are within reach of a coal-fired power station, where crops can be grown for co-firing.

The alternative method, anaerobic digestion, can make use of biomass at any moisture content. Indeed it performs best with higher moisture content crops prior to the lignification of cells in the plant material.

Annual or perennial crops grown and used as feedstock for digestion in anaerobic digester systems can be grown as part of a conventional cropping rotation, for example forage maize, whole crop cereals, grass, clover leys, sugar and fodder beet all are suitable as feedstocks for co-digestion. Other crops worthy of consideration include hemp and comfrey of which both produce prolific biomass at relatively low input costs.

Using higher moisture content green crops reduces the energy and cost requirements of crop drying and also allows harvest during the dryer summer/autumn seasons. The use of these crops is the single most influential factor in the incredible increase of on-farm biogas plants throughout Germany and Austria in recent years.

Co-fermentation of energy crops

Co-fermentation of energy crops with manure has transformed the whole biogas industry. The number of livestock on a given holding is not the limiting factor, as the manure can be supplemented by any quantity of energy crop. This gives the producer much more control over his electrical output and overcomes the greatest drawback with dairy/beef farm biogas plants, which is the reduction of manure supply during the summer months.

Because the energy crop has not been previously digested it has up to ten times the energy value of manure for a given quantity. This has the effect of raising the energy value of the feedstock per cubic metre of capacity of the digester, thereby making more gas per cubic metre of the digester, and reducing the capital cost per m³ of gas produced.



Graph showing gas output in m³ per tonne of material

From this graph it can be seen that the traditional feedstocks of cattle and pig manure are at the lower end of the production graph whilst grass and maize silage are near the middle at approaching 200 m3 of gas per tonne.

Of course manure is a free feedstock, whereas the crops have to be grown. Whilst the growing costs have to be taken into account, the current profitability of both crop production and conventional milk and meat production, growing crops for biogas production compares extremely favourably.

Crops grown for this form of energy production can be grown on set aside land and also qualify for the Energy Crop Premium Scheme, currently paying 45 euros per hectare.

Another factor to be taken into account in the growing of these energy crops is that the digestate contains all of the nutrients used by the plant in the growing cycle. This can then be spread back onto the land to provide the nutrients for the next crop with the minimum of supplementation; as a result, this is a closed loop system for the nutrients which reduces the cost of growing the crop and reduces the environmental impact of crop production.

The following graph shows the respective outputs from 200 ha of different crops and the potential electrical output from these crops with an electrical conversion efficiency factor of 35% (for instance 35% of the input energy is turned into electricity)

Feedstock	Tonnage	Output, kWh	Biogas production
Maize silage	9000 t	>400 kW	1,800,000 m ³
Rye-grain	3000 t	>150 kW	660,000 m ³
Grass silage	6000 t	>250 kW	1,200,000 m ³
Sugar beet	11000 t	>350 kW	1,680,000 m ³

As can be seen from this chart, maize silage comes out well to the fore, although this data is from Germany where grass production is not as prolific as in the West Country of the UK. However for mainland Europe, maize is becoming the principal energy crop.

Recent research work being carried out within Germany is looking at the merits of bi cropping, for example multi species whole grain crops such as rye, triticale, and wheat grown in the same field and also a combined maize/sunflower crop. There is even a DTI research paper on the merits of utilising grass and red clover for biogas production, and a common theme with all these researches is to ascertain the role of utilising the digestate as the sole fertiliser source, thus reducing input costs and improving the situation regarding possible ground water pollution from excess fertiliser applications.

Many German farmers started out co-fermenting crops with their manure but have now dropped their livestock enterprise and are concentrating on the production of energy from crops as it pays better than livestock farming! There are also examples of units set up and running on silage alone with no manure used at all, apart from being used to "seed" the digester during the start up phase.



Biogas Plant in Austria

Powered by maize crops only.

Supplied by 60 farmers.

Anaerobic digestion and waste treatment

The fundamental factor for organic waste is that it originated from the land and with society now realising that in order to be sustainable it has to be returned to the land as part of the nutrient cycle. The UK now has a population of sixty million people under some of the densest conditions found in the world. All of this waste has to be dealt with in a sustainable manner, and increasingly this means being returned to land.

Whilst the production of the food they consume is increasingly being sourced from overseas, as market forces and supermarket policies lower the percentage of food supplied from local producers, the disposal of the residues from all of the production will be returned to UK land. This fact is very much underestimated by policy makers. For UK farmers to be involved in the return of these residues to their land, they also need to be involved in production from the land to be able to utilise the nutrient load from these residues.

As the residues have to be returned to the land, access to land for spreading is crucial and this creates a huge opportunity for farmers to become involved in this developing arena.

Whilst gate fees can contribute up to 50% of turnover to a business generating electricity from this type of feedstock, there are many other factors that need to be taken into consideration with this type of operation. These additional considerations centre on the regulatory issues around waste disposal.

Whilst processing of farm generated residues and crops have little in the way of regulatory issues to contend with, taking in waste streams generates a much higher burden, but given due consideration they should be surmountable.

Physical issues with regard to the spreading of the digestate from these feedstocks relate to use of crops produced from land where digestate has been spread, and bio-security issues with grazing animals. However by matching waste streams with individual farm factors these issues should not preclude the placing of anaerobic digestion units, that can treat selected waste, onto livestock farms. Waste streams offer the chance of low cost or income generating feed stocks which could make a useful contribution to the successful operation of on-farm biogas production.

Economics of biogas production in the UK

The economics of operating a profitable on-farm biogas enterprise here in the UK are dependent upon several varying factors.

The main factor is the electricity price. This is supported by the ROC scheme, which is currently under review, and is likely to reward electricity generated by this technology with an enhanced level of payment. During the time of my study, the price that could have been achieved by a biogas plant has ranged from 7.5 pence per kWh to 10.25 pence per kWh.

The other critical factor regarding output is the percentage operating time of the CHP unit. If the unit isn't running, it isn't earning and this is where support from the technology provider can help. In Germany the range is from 63% of full time running to 97%. Needless to say, one needs to be near the top of this range to be economically viable.

Income can be further increased if a use can be found for the heat. There are many ways that this can be utilised, from heat sales to third parties, to creating new on-farm enterprises to utilise the resource.

As described above, the inclusion of some form of organic waste as a feedstock can also have

a positive effect on the economics of biogas plant operation.

The economics of biogas plant operation vary according to many factors, the main ones being:

- •Economies of scale
- •Price received for different outputs
- •Proximity to a suitable electrical connection point
- •Cost of feedstocks

Each of the above has a bearing on the economics of each project; however there are a few rules of thumb that could help a potential developer of a biogas plant.

The smallest size that is likely to be economical under UK conditions is around 250 kWh with the most economical likely to be between 1-2 mWh.

Regarding feedstocks; one hectare of energy crops will produce over 2 kWh of electricity for a years operation (for example a 250 kWh plant would need a land area of 125 ha to power it) if there were no other sources of feedstock (waste or manure).

As each project is very site specific, economics are hard to generalise. I have included a sample budget of the plant planned on my own farm to act as a guide. This is for a 340 kWh unit with manure from 400 dairy cows and 97 ha of energy crops.

Income 2,829,480 kWh @ 9p	£254,653
Costs:	
Feedstock	£ 38,520
Other - Maint, Labour etc	£ 73,140
Total Costs	£111,662
Operating Margin	£142,991
Capital Cost	£741,562
Operating Margin	£142,990
Finance Costs	£ 75,390
Margin	£ 67,600
Project Return	19.28%

The above figures are for example purposes only; however they do give an indication as to the potential returns available from an investment in a biogas plant.

The UK energy market

I have been lucky in my timing of this topic, in that since commencing the study, the issue of fossil fuel supply and the necessity to find alternatives has become a mainstream subject. The concentration of fossil resources in the hands of countries less than sympathetic to western countries, the huge and seemingly unpredicted rise in prosperity of China, India and other 2nd world countries with their associated demand for energy both add tension to a market that is approaching supply maturity and the peak of production which once reached, will lead to an inevitable decline in production and an increase in cost. Couple this with the increasing evidence of, and concern about climate change and carbon emissions, renewables are now featuring high up the list of alternatives and the time for action to address these concerns is upon us.

The move from net oil exporter to net importer, at a time of high prices and the announcement that the natural gas reserves we have will decline quicker than expected have coincided with

the reality that we will be relying upon gas imports from the USSR for over 60% of our gas requirements by 2020. The actions of Russia turning off the gas supply to the Ukraine was a warning that even the complacent UK government took notice of, and the Prime Minister has noted that Russia is using its energy reserves as a foreign policy tool.

The recent energy review document (July 06) has raised the market for renewable electricity to 20% of the market.

Electricity has to be produced close to the point of consumption and cannot be imported (limited nuclear electricity from France being the exception!). Beyond the looming international energy crunch, there are further supply pressures building from within the UK electricity industry. Following years of production, at or below the cost of production, the electricity generating industry has had to increase the price of electricity to consumers by around 50% in the last two years.

Most of the UK's generation capacity is in the north of the country, however as we move from an industrial economy to a service based economy, the consumption of electricity is moving towards the south. This gives rise to problems within the electricity distribution network, as more power has to be moved towards the south, necessitating the construction of new or upgraded power lines and these are not popular with the locals in areas that have power lines travelling through them, causing delays or worse, to the upgrading plans.

Another area that is adding tension in the market is the fact that most of the UK's electricity generation stations will need to replaced within the next 15 years. The coal stations have to be extensively modified or rebuilt to meet emissions standards and the nuclear stations are all scheduled to be decommissioned by 2023, leaving only the more recently built gas stations that will remain in commission.

A fact often unknown is that at least 7% and up to 12% of generated power is lost through heat generation in the power lines as power is transformed up in voltage and then stepped back down again near to the consumer. The government has identified embedded power generation with combined heat and power units (CHP) as a way of not only reducing these losses but by using the heat produced as a by-product of electricity generation to replace stand alone heating systems, the energy efficiency per unit of fuel increases from 30%-40% to up to 85%.

Further pressure to choose renewable fuel supplies are coming from local authority building regulations, where a percentage of a new developments energy requirements should be sourced from renewable origins. These are all areas of policy that are showing that the UK is finally catching up with more forward thinking countries and the debate amongst leading central government figures on green policies and things such as personal carbon emission entitlements, indicate that further moves towards a renewable friendly policy will follow, creating real markets for farm produced energy.

It appears that as the era of cheap energy closes and environmental concerns grow, the age of large centralised generating stations could be passing. Local power production is increasingly looking more credible. The UK now has a stated aim of becoming a low carbon economy.

Conclusions for UK agriculture

•The concept of coupling the benefits of local CHP alongside a locally produced renewable fuel and a new market to provide people with heat and power from the land is opening up for UK farmers.

•With biogas technology, UK agriculture will be able to supply both electrical power and heat markets.

•The market for energy is growing, not only in the emerging economies, but also in the first world economies. Also, world energy consumption is set to rise by 71% by 2030, providing an excellent opportunity for a local reliable and renewable energy source, as provided by biogas.

•By buying into existing expertise we will save both time and money and avoid 'reinventing the wheel'. By adopting the latest proven technology from other countries we can have a competitive reliable biogas industry from day one.

•The German biogas industry is the world leader, in both size and technology.

•The latest German equipment offers process guarantees. The adoption of such technology would enable the UK to gain access to the most efficient, reliable technology thereby reducing the technology risk aspect of this new market place.

•Biogas production has the advantage that it has a potential role for nearly all farmers. For livestock farmers it can extract an income from the manure of the livestock, whilst improving the fertiliser value, reducing the odour and fly problems that are associated with manure and also mitigate uncontrolled methane emissions. For arable farmers it offers the option of an alternative break crop and the opportunity to add value to crops grown on the farm.

•The factors previously outlined in the UK energy market section point to a new market place for agriculture, which has the effect of giving farmers more marketing options that will increase the competition for our production from both new and existing markets. As the Times newspaper reported on its coverage of the publication of the Stern Report. (Nov 06) "The Demand for new power sources will become the most disruptive force in business since the internet".

• Biogas has a good energy balance, and can use a wide range of feedstocks. Both of these factors make biogas less susceptible to the negativity of the fuel vs. food debate that is currently being used against biofuels generally.

•My final conclusion draws from the ethanol sector in the US, and biogas sector from Germany. For farmers to maximise the gains from this new market place they need to be at the forefront of investing in the upstream process, and not remain as pure feedstock providers, as we have become throughout the food chain.

Personal conclusions

I started out on the study with the idea that there was a market for renewable energy within the UK in the form of the ROC scheme, and that there appeared to be a successful biogas market in Germany and I was keen to find a way of making on-farm biogas production and utilisation profitable for UK farmers.

I also stated in my application form, that whilst wishing to remain in mainstream farming I was keen to find a diversification venture that would compliment my farming enterprise.

As my study progressed and my knowledge increased I became more convinced that anaerobic digestion could work under the UK conditions and have been working towards arrangements for the construction of the UK's first crop powered on-farm biogas plant at Lowbrook Farm, Dorset. Developments have progressed to the stage that I have now achieved planning and all other consents to build a 340 kWh unit powered by manure from the 400 dairy cattle on the farm and 160 ha of maize. This will not only give me new income streams, but also give me a profitable break crop for my arable enterprise.

Further to the on-farm development, the interest in the topic has become such that I have now established a range of business ventures based around anaerobic digestion.

To conclude, not only has my study enabled me to travel and visit areas that I have always wished to visit, I have found the company of my fellow scholars enlightening, fun, and a very stimulating experience.

I have researched a topic that I believe holds a great opportunity for British farmers, and found the alternative enterprise that complements my existing business.

I have been privileged to meet many different people on my travels, and at all times I have been received with courtesy and enthusiasm, and have been shown much kindness by people who have gone far beyond that which I could have expected.

There can be no doubt that whilst information can be gleaned from different sources, to be able to look someone in the eye and be given an answer passes on much more information than from a passive source.

I have gained a fantastic insight into what I believe will become a huge opportunity for UK agriculture, and without the kindness of my hosts, sponsors, family, staff and friends I would not have been able to make the most of the opportunity that Nuffield has offered me.

Stop press

On Wednesday 23rd May 2007 the government announced an Energy White Paper that will band the ROC.

Anaerobic digestion has been granted an allocation of two ROC's per megawatt hour of electricity.

This has doubled the green premium that electricity from biogas will receive and not only indicates the government's strong support for the technology, but also makes the economics of electricity from biogas even more compelling, and will give UK biogas plant operator's a similar price to that received in Germany, where biogas is booming. This price is likely to be around 11.5 pence per kWh.