A Detailed Economic Assessment of Anaerobic Digestion Technology and its Suitability to UK Farming and Waste Systems

2nd Edition

ANDERSONS

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NNFCC

Written by:
The Andersons Centre
Old Bell House
2 Nottingham Street
Melton Mowbray
Leicestershire
LE13 1NW

Graham Redman
Research Economist

Mobile: 07968 762 390
Office: 01664 503 200
E-mail: Gredman@theandersonscentre.co.uk

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1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

This compendium of information and resources for anaerobic digestion (AD) addresses key questions that need answers and barriers to resolve to build an AD plant primarily at farm level. This is the second edition of this report. The first was published less than 2 years ago which illustrates how quickly the industry is moving forward in size, experience and knowledge. Policies have changed dramatically in the mean time, including both the financial incentives, the environmental requirements and quality assurances and new refinements are also currently being negotiated regarding environmental and planning regulations.

AD is the conversion of feedstock (any organic non-woody material) by micro-organisms in the absence of oxygen into biogas and digestate. It is a natural process and is well understood by man having been harnessed for many years. AD potentially benefits several sectors of society including the farmer/entrepreneur, the food processing sector, the local community, the environment and government as follows:

Table 1 ~ Benefits of AD to Different Groups

Farmers	Food Processors	Local Community	Environment	Government
Profit	Food waste removal	Less smell	Less nitrate pollution	Landfill Directive
Available nutrients	Cheaper option	Local renewable energy	Carbon saving	Renewables Obligation
Pathogen kill	Good image	Local heat supply	Diverts land fill	Fuel security
Diversification		New jobs	Diverts incineration	RTFO
Weed seed kill		Cleaner environment		Decentralised electricity

AD can benefit from various Government policies. These are:

- Renewables Obligation
- Climate Change Levy
- Renewable Transport Fuel Obligation and Excise Duty reduction for Biofuels
- Landfill Tax
- Landfill Allowance Trading Scheme

Most biogas produced in the UK is used to generate electricity. This is considered the standard use in the study. The Renewables Obligation (RO) and Climate Change Levy support generations of renewable electricity in the UK. The Renewable Transport Fuel Obligation is a similar policy to the RO that encourages the use of renewable road fuels. Landfill Tax and the Landfill Allowance Trading Scheme are designed to reduce the amount of organic wastes being land-filled. Alternative waste removal processes including AD are therefore supported. There is little evidence to suggest the Nitrates Directive assists the AD industry, on the contrary, it is an obstacle in many situations.

In spring 2010, a Feed-In Tariff will be available for renewable electricity generators of less than 5MW capacity (all non-water company AD plants in the UK are currently less than 3MW). This will be a fixed guaranteed price for 20 years. Then, in spring 2011, it is planned a Renewable Heat Incentive will be implemented to encourage the development of a renewable heat sector. AD will benefit from both of these schemes.

Various other policies exist throughout the EU and rest of the world. They include some specific AD policies, others limiting or banning landfill and incineration of organic waste. Minimum guaranteed prices for electricity from AD, soft loans and capital grant schemes for AD investments are included.

Consequently, the numbers of biogas plants globally vary enormously between countries. The UK probably has about 30 plants (excluding water companies), some not farm based. Other countries such as Germany have about 4,000 and China has probably over 30 million but extremely small household digesters. AD in small villages with minimal infrastructure is useful for sanitation, fertiliser and fuel (cooking or heating) provision. The number in the UK is expected to rise sharply over the next five years.

1.2. Technical Summary

The microbial process of anaerobic digestion requires careful management to maximise its potential output. There are several design options including:

- Temperature to operate at
- Moisture levels
- Continuous or batch system
- Single, double or multiple digesters
- Vertical or horizontal tank layout.

These all have different cost implications as well as special requirements, and return varying efficiencies against different most limiting resources. Some feedstocks are more suited to particular combinations of the above options. Depending on the feedstock and where it has been sourced will also affect any necessary pre-treatments such as chopping, blending, weighing, packaging removal or pasteurisation.

Anaerobic digesters should be fed on a ‘little and often’ basis. Digestate will be removed at the rate at which feedstock goes into the digester, less the small (usually 3-10%) fall in volume from the production into biogas. Depending on feedstock and system used, digestion can take as little as a day or two up to 2 months in some circumstances. The gas is then cleaned of contaminants (which include the highly corrosive hydrogen sulphide, moisture and other particulates and chemicals) depending on its intended end use. Biogas destined to be used for electrical generation requires only a simple clean to protect the generating equipment.

Starting a digester could take several days to fill, more to heat, and possibly weeks to create a microbial culture suitable to the feedstock. Once operational, it can be straight forward to manage, depending on how hard it is pushed, and how variable the feedstock.

Some plants throughout Europe and one in the UK are Centralised (CAD) meaning they are supplied with slurry by several farms. These can be enormous and highly efficient, creating large amounts of biogas but raises transport costs, requires good cooperation and issues like planning consent and managing supply chain logistics become more demanding.

Maximising yields of biogas is dependant on getting several variables right. These include moisture content, pH, carbon: nitrogen ratio, correct feed blends and time spent in digestion. Typical on-farm feedstocks are slurry, vegetable wastes, grain and meal, silage, dairy wastes and other primary processing wastes. Clearly the yields of different feedstocks will vary enormously too in line with their calorific values. Example yields per tonne wet weight are summarised:

Table 2 ~ Biogas Output from Various Feedstocks

Feedstock	Dry Matter %	Biogas Yield m^3/tonne	Value of Biogas £/tonne*
Cattle Slurry	10	15 – 25	4.70 - 7.90
Pig Slurry	8	15 - 25	4.70 - 7.90
Poultry	20	30 - 100	9.50 - 31.70
Maize Silage	33	180 - 220	57.40 - 70.00
Grass Silage	28	160 - 200	50.50 - 63.40
Maize Grain	80	500	160
Whole crop wheat	33	185	58
Rolled wheat grain	85	610	190
Crude Glycerine	80	580 - 1,000	185 - 320
Rape Meal	90	600	190
Fats	Up to 100	Up to 1,200	Up to 380
** at current standard prices assuming FITs policy (see chapter 3)*			

Knowing the likely biogas yield of feedstocks allows the manager to calculate the values of outputs (electricity, support and heat). Other feedstocks from non-farm sources not only provide a higher gas yield than many on-farm sources, but might also provide revenue from gate fees. However this introduces another cost layer including meeting regulatory constraints and administrative requirements. These will vary depending whether they are green (plant) wastes or contain animal residue (Animal By-Product, ABP). Gate fees rise according to the level of licensing the plant has achieved (green or ABP).

The biogas tends to be used for electricity and heat production although it could be sold for mains gas or road fuel. The highest returns from electricity sales can normally be achieved via private wire directly to consumers. However, most is sold via the national grid, presently through a 'power purchase agreement'. These vary considerably according to the level of risk/security required and flexibility of the provider.

Connecting the plant to the electrical grid can also be a major task possibly requiring large-scale rewiring of nearby sections of the grid as well as the connection to the plant. Various factors affect the cost of this including:

- The existing capacity of the nearby network
- The peak load capacity of the AD plant
- The distance to the nearest suitable 3-phase connection point.
- Location on the network

- Negotiating skills

Digestate makes a good fertiliser, currently worth around £6/m^3. Not only does it have slightly higher N, P and K content than slurry, the nutrients are more available for plant uptake, especially in the liquor component. Its drawback is the nutrient mixture is fixed, so its application to land should stop when the first nutrient requirement is met. Separation of the liquor from the fibrous fraction may facilitate both storage and spreading procedures.

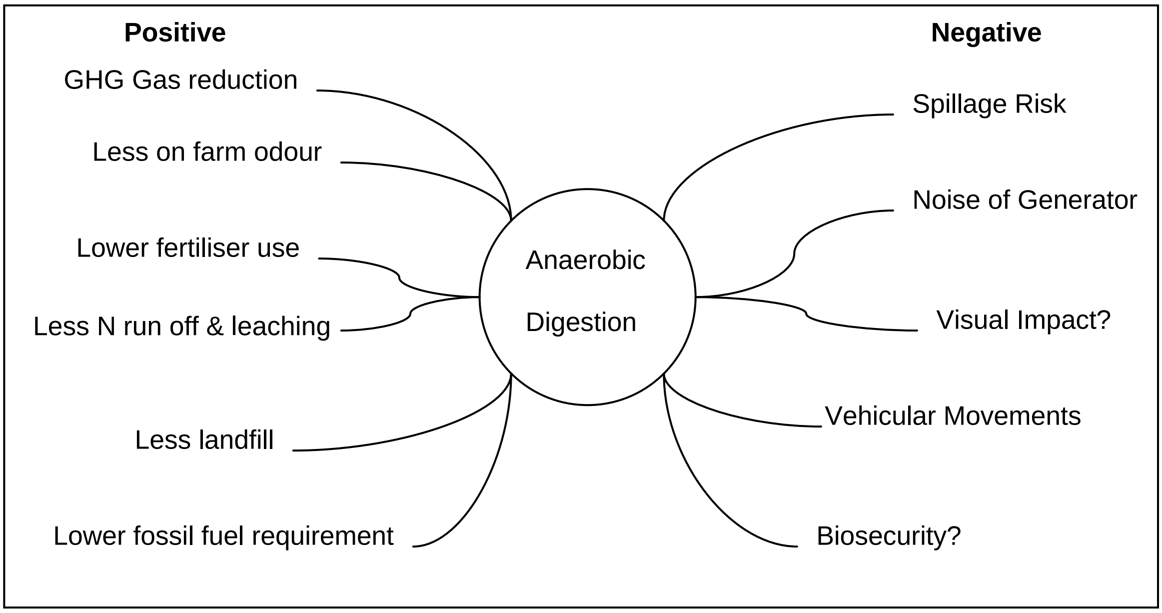
1.3. REGULATIONS

The regulatory controls are designed to safeguard the environment, local planning system and animal and human health. These are

- **Duty of Care**; a duty that all waste holders have to ensure it is properly disposed.
- **Environmental Permitting**; different levels of environmental requirements depending on the environmental risks each facility presents.
- **Waste Carriers Licensing**; for those transporting waste.
- **Animal By-Products Regulations**; for anybody handling animal by products.
- **Digestate Accreditation**; ensuring the digestate meets minimum standards.
- **Planning Procedures**; necessary to regulate the built environment
- Meeting **Cross Compliance** requirements for those claiming the Single Payment
- Conforming to **Environmental Stewardship** rules if the farm is with an ESS agreement.
- **Health and Safety**; because safety is paramount.

Other procedures are in place to become accredited for certificates (ROCs and LECs) which have a value. A biogas installation can affect the environment in the following ways:

Figure 1 ~ Illustration of Potential AD Environmental Consideration



Each AD plant will not necessarily need to meet each of the regulatory controls but will depend on size, feedstock and digestate use.

Not all AD plants need planning consent but for those that do, it can be a major hurdle to overcome. This is largely down to general ignorance of what a biogas plant actually is and the NIMBY (Not In MY Back Yard) attitude. Planning Policy Statements 7 and 22, 'Sustainable Development in Rural Areas' and 'Renewable Energy' both require referencing.

1.4. ECONOMICS OF AD ON FARM

Revenue from AD should be achievable from a number of sources. Electricity, heat, policy incentives, digestate and gate fees where relevant are all valuable outputs. Offsetting existing costs in the farm business such as heating bills, farm electricity usage and fertiliser requirements will also contribute by saving costs. The interactions between the AD plant and the rest of the farm business will also often be beneficial with shared resources such as labour and machinery.

A major challenge for the operator is to remain at full capacity for as much of the year as possible, any down time or periods of operating at less than full capacity will swiftly erode the end of year margins. Most expect an efficiency of at least 85% of potential capacity, some operations achieve far less (and lose money) and others are up in the high 90's.

The two major costs associated with AD are usually the capital set up and associated finance, and feedstock (if home grown or purchased feed is used). Operating and maintenance costs such as insurance, labour and utilities are usually relatively low. The high capital cost of setting up an AD plant means the enterprise should be considered a long-term operation, the longer the capital is operating, the greater its overall return should become.

Grants are available to assist with the capital cost. Some of these though may create a barrier for receiving Feed In Tariffs. Failing this there are considerable amounts of private finance keen to assist well managed AD businesses and the Enhanced Capital Allowance scheme is also available to offset the capital expenditure on Combined Heat and Power (CHP) generators in the first year.

As a general rule, as long as they remain at full capacity and don't take on considerable additional management or operational costs, larger plants are more efficient. They are dearer to build but cheaper per cubic meter of capacity. Larger generators are more efficient as a general rule and negotiating contracts for larger supply volumes can provide greater leverage. However, as plant size increases, so do the stakes, with more factors becoming increasingly fundamental to the success of the plant.

AD Calculator: A calculator has been built by the same author and is freely available alongside this report designed to assist those involved with AD to assess the viability of projects. Like this report, it has been reviewed and updated as of February 2010 to include new policies and knowledge on AD.

1.5. CASE STUDIES

Six case studies range from a very small 300m^3 digester taking 17.5m^3 cattle slurry per day to an enormous 7,200m^3 centralised plant devouring over 30 times the volume. Both of these plants have been operational for in excess of 15 years illustrating the sustainability of the business concept. Three other systems examined include one based on third party waste streams mixed with pig manure, raising a large proportion of its revenue from high value gate fees. Another digests pig manure augmented with maize and glycerine, so feedstocks are purchased, a fundamental difference to the previous example. The fifth case study is a simulation on realistic figures for the construction and development of a totally farm fed system. It is based on a dairy business but with the majority of its feed being ensiled energy crops. Whilst no feedstocks are brought onto the farm, using crops from the farm business incurs considerable internal costs. The last case study examines a farm undertaking a feasibility exercise and some of the issues raised in the process.

These studies illustrate the challenges of differing systems and the potential financial outcomes. All are profitable, albeit some more than others in terms of return on capital. The studies illustrate that depending on the system implemented, on-farm AD is not necessarily a high return enterprise without the assistance of capital grant support.

1.6. Sensitivity

Using the fifth case study to explore changes in profitability from small movements in key variables exposes some important responses. As capital and feed costs are the two dominant costs, changing these two by relatively small percentages has the greatest impact on return. Feedstock cost changes alter the business for a single year whilst capital costs affect the business by less but for several years.

A change of electricity price by only 1p/kWh is enough to move profit by £33,400. It highlights the importance of negotiating the best terms available. Changing the efficiency of the plant has big implications. Remaining operational for an additional 5% of the time adds a considerable 2.8% on the return on capital.

1.7. Biomethane Injection into the National Grid

When the methane in biogas is purified, it becomes ‘biomethane’. The removal of carbon dioxide, moisture, sulphurous compounds and particulate matter raises its calorific value and can be used as a natural gas replacement. This purification process is not cheap to install so the incentives should be in place to justify it. Gas is used more efficiently than electricity so this is environmentally more beneficial. The future of biomethane could be more positive when Renewable Heat Incentives are implemented in 2011.

1.8. Biomethane as a Road Fuel

Environmentally, it appears there is nothing to compete with biogas as a road fuel. However, constructing an infrastructure to supply such a fuel, generating sufficient demand then ensuring sufficient supply to meet the demand is a mammoth task. It is achievable as proven by the Swedish with approaching 12,000 vehicles in Sweden driving the equivalent of 250 million car miles per year on the fuel. It has taken considerable time and expenditure in tax concessions, grant funding and other ‘perks’. In the UK some companies are experimenting with Compressed Natural Gas (CNG), a natural gas equivalent using the same technology. Duel fuel (running on blended diesel and biomethane), bi-fuel (which can run on either biomethane or petrol) and dedicated biomethane fuel engines are developed and used throughout the world, all that is required in the UK is the incentive to develop an infrastructure.

1.9. CONCLUSIONS

This sector of the Renewable Energy industry, itself very young, is promising opportunities for those positioned and eager to capitalise on them. There are several potential pit-falls that this study has highlighted. Profitability can be good, and should be augmented in April 2010 following the implementation of the Feed-In Tariffs and 2011 from the Renewable Heat Incentive.

Making a profitable AD business purely from slurry is very difficult as the gas yields are so low. Augmenting them with farm produced waste streams (such as vegetable wastes) could enhance the yields but introducing energy crops will make a considerable impact, although also adding costs into the business. Introducing third party waste streams requires alterations to the business structure, with regulatory requirements and administrative necessities, but can make the business far more profitable by adding high yielding feedstocks for a fee rather than payment. The level of management required is raised at this point.

The production of biogas through AD can potentially augment the carbon footprint of several businesses simultaneously. Those that divert their organic waste from landfill or incineration, the farm business itself, and potentially the company that buys the ROCs, although, technically, transfer of ROCs is a sale of the environmental credentials. Rising appreciation of the necessity to reduce environmental footprints is already giving the AD industry a boost.

Biogas has the potential to add value to a farm business by sharing resources such as silage, digestate, labour and machinery. It could also encourage co-operation between nearby and neighbouring farm businesses. Each business has a different range of spare capacity in several resources, such as labour, machinery and so on suggesting that between two organisations, fewer additional costs might be necessary. This is something the Danes have mastered.

Finally, it is clear that, as in any new major diversification enterprise on farm, there is a considerable learning curve to climb and some big decisions to be taken. This requires level headedness, conviction and commitment.

2. INTRODUCTION AND BACKGROUND TO ANAEROBIC DIGESTION

Chapter Summary

- AD is the digestion of organic feedstocks in the absence of oxygen, producing biogas and digestate.
- AD can provide benefits to government, farmers, food businesses and the local community.
- AD assists with waste disposal and produces green energy and other environmental solutions
- There are government policies providing support for AD.
- The UK industry is growing but is more developed in many other countries.

2.1. PURPOSE OF THIS DOCUMENT

This Second Edition of a study on anaerobic digestion (AD) draws together the issues and important details for small and large scale organisations considering diversification into AD. It focuses primarily on utilising on-farm feedstocks but explores third party feedstocks in the form of non-agricultural waste and also joint ventures including central anaerobic digestion (CAD).

Opportunities for AD to be incorporated into UK farm systems are developing very quickly in the light of growing environmental and energy security issues. Combining the techniques of AD and traditional farming practices is a relatively novel concept in the UK, but less so elsewhere. The NNFCC commissioned this evaluation to guide people through the maze of information necessary to make correct and sound decisions about anaerobic digestion. Despite the very positive talk about the profitability of AD, it is not *always* the right thing to do.

AD Calculator: A calculator has been built by the same author and is freely available alongside this report designed to assist those involved with AD to assess the viability of projects. Like this report, it has been reviewed and updated as of February 2010 to include new policies and knowledge on AD.

2.2. WHAT IS ANAEROBIC DIGESTION?

AD is the conversion of organic non lingo-cellulosic (non-woody) material, the feedstock (also known as substrate), by micro-organisms in the absence of oxygen into stable and commercially useful compounds. The process can be likened to composting except that composting is aerobic, involving oxygen in its breakdown of organic matter. AD feedstock can be unwanted 'wastes' (such as slurry) or energy crops (such as maize silage) grown specifically for feeding the AD plant. The product groups of the digestion process are:

- Biogas. This is a mixture of about 60% methane, 40% carbon dioxide and traces of other 'contaminant' gasses. This is then combusted to generate electricity, heat or used as a road fuel.
- Soil conditioner. This is an inert and sterile wet product with valuable plant nutrients and organic humus. It can be separated into 'liquor' and fibre for application to land or secondary processing.

AD is a natural process. It is not new to mankind having been harnessed and used by man for thousands of years. The science is well understood and has been adapted to several environments, feedstocks and purposes globally. In the UK, AD has been used for several years, mostly in the sewage industry, digesting raw sludge to a safe, inert and low-odour product that can then be spread on land as a fertiliser. Not only does it help solve a waste disposal problem, but also provides useful and commercially valuable products.

2.3. BENEFITS OF AD

The potential benefits of AD are multiple. They are listed here as benefits to farmers and entrepreneurs, the food processing industry, the local community, the environment and government:

Benefits to Farmers and Entrepreneurs:

- Can be a profitable diversification opportunity providing market options for green power and heat
- Provides more available nitrogen than slurry, meaning better crops and lower fertiliser bills
- Kills most pathogens in the feedstock, thereby killing feedstock borne diseases
- Kills virtually all seeds in the feedstock, thereby preventing spread of weeds

Benefits to Food Processing Industry

- Easier waste recycling compliance
- Cheap compared with incineration or landfill
- Rodent and vermin control is easier than with other waste disposal techniques
- Environmentally sensitive organic waste treatment improves company image, good for marketing

Benefits to the Local Community

- Odour levels are far lower than with raw slurry (80% lower) or organic waste
- Energy from renewable sources
- Potentially provides heat to harness for local use
- New jobs (and potential related business)
- Cleaner environment

Environmental Benefits

- Can reduce nitrate pollution by decreasing run-off to water courses from slurry spreading
- Harnesses energy through methane capture with no net release of greenhouse gasses (GHGs)
- Can reduce the amount of biodegradable waste sent to landfill or incineration
- Can be not only carbon neutral but carbon saving if diverting waste from landfill or incineration.
- Provides useful fertiliser for land application offsetting the demand for inorganic nitrogen

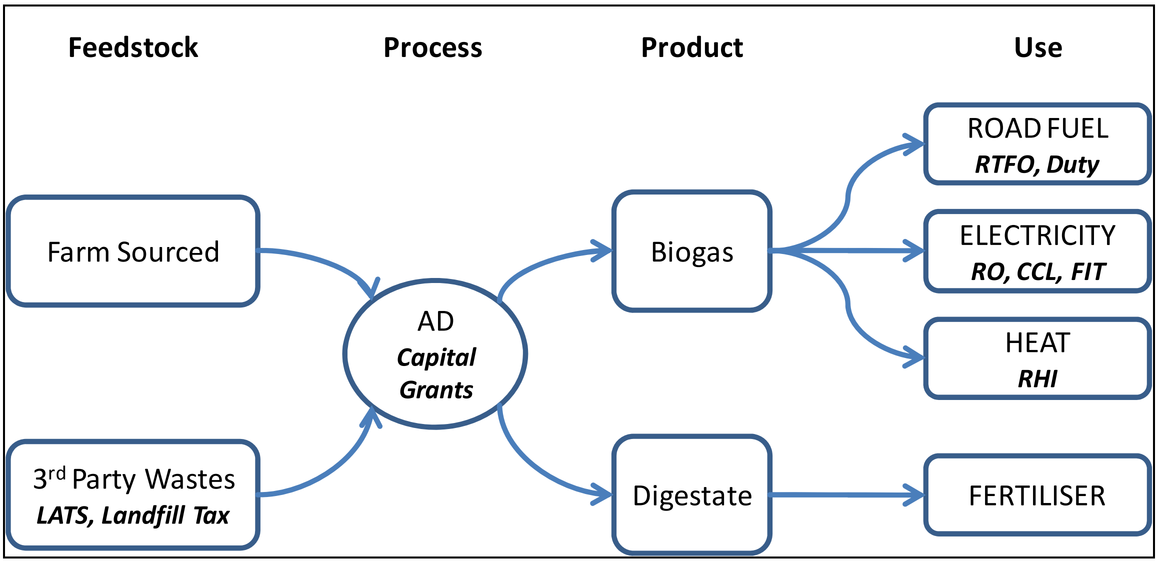
Government Benefits

- Helps meet the Landfill Directive reducing organic waste to landfill
- Can assist Local Waste Authorities tackle the Landfill Allowance Trading Scheme
- Contributes towards achieving the renewables targets encompassing Renewables Obligation and Renewable Transport Fuel Obligation
- Starts to address the fuel security issue
- Decentralises electricity and heat provision

2.4. Government Incentives to Encourage AD

There are two strands of government policy; firstly, a range of renewable energy incentives, and secondly, policies designed to address a range of other environmental problems. Figure 2 highlights the areas where AD operations may benefit from policy incentives.

Figure 2 ~ Parts of AD that attract Central Policy Support



AD can directly benefit from and indirectly tap into several policies, thereby gaining government support (UK and EU). Each has different effects on an AD business depending on how the business is set up and what the biogas is used for. Those that are currently most likely to advantage the AD industry are listed below[1].

- The Renewables Obligation (RO)
- Climate Change Levy
- The Renewable Transport Fuel Obligation (RTFO) and biofuel excise duty reduction
- Landfill Tax
- Landfill Allowance Trading Scheme (LATS)

As of April 2010 and then April 2011, it is expected that additional forms of support, Feed-in-Tariffs (FITs) and Renewable Heat Incentives (RHIs) will become the primary vehicles of AD support. An AD operation is not always eligible for government incentives. For example, if it uses solely farm yard manure and slurry and generates only heat from burning the gas, then no government support is currently available (although the chance of attaining capital support is probably far higher (refer to page 73). However, if a third party 'waste' stream is used as a feedstock, and the gas is used for either electricity generation or as a road fuel, then benefits (either direct or indirect) can be gained from the Landfill Tax and the Renewables Obligation for electricity production or the Renewable Transport Fuel Obligation and the Excise duty discount for biofuels (until April 2010 when it ends, being replaced by an enhanced RTFO policy). Since harvest 2009, the Energy Aid Scheme is no longer available.

[1] *Capital grant schemes are available and discussed in section 5.4, on page 73*

The process of electricity generation is treated as the 'normal' use for biogas in this report, being its primary end use in the UK. The cleaning of biogas into biomethane for alternative uses and generation of road fuel is discussed in chapters 8 and 9 on pages 103 and 107 respectively. Renewables policies are in place to support electricity and road fuel but there is nothing currently supporting the provision of renewable heat. This therefore makes the production of biogas for selling onto the national gas grid presently unattractive but Renewable Heat Incentives could change this from 2011. The UK Energy Act (November 2008) enables government to, amongst other things, establish a financial support mechanism for the provision of renewable heat - the Renewable Heat Incentive (RHI) for Great Britain.

2.4.1. The Renewables Obligation

The Renewables Obligation (RO) (also the Renewables Obligation Scotland and the Northern Ireland Renewables Obligation) is a policy designed to encourage the generation of electricity from renewable sources. It sets a non-obligatory target for licensed electricity suppliers to gain a minimum number of Renewable Obligation Certificates (ROCs) each year proportional to their total electricity supply (1 ROC per MWh up to the target). The target rises annually as laid out in Table 3. ROCs are earned by any business supplying electricity from renewable sources.

ROCs are earned at different rates from different renewable energy sources (ROC banding). For example, one ROC is earned from the generation of 1MWh electricity[2] from onshore wind turbines, 667kWh from co-firing energy crops with combined heat and power (CHP) and 500kWh from AD (or 2 ROCs per MWh, 'double ROCs')[3]. The policy is not actually an obligation to achieve these target levels, but to participate in the scheme. The incentive to meet the RO target is two-fold:

1. Any supplier missing its ROC target is charged £30 per ROC missed. This is index linked at 2002/03 RPI levels making £36.99 in 2010/11.
2. A 'buy-out' fund is generated from these penalties and redistributed equally to every ROC registered by the administrator (OFGEM)[4].

Table 3 ~ Renewables Obligation Target for Licensed Electricity Suppliers

Year*	***Renewables Obligation Target*** *(of total electricity output)*	Non-compliance Penalty per ROC
2002/03	3.0 %	£30.00
2003/04	4.3 %	£30.51
2004/05	4.9 %	£31.59
2005/06	5.5 %	£32.33
2006/07	6.7 %	£33.24
2007/08	7.9 %	£34.30
2008/09	9.1 %	£35.76
2009/10	9.7 %	£37.19
2010/11	11.1 %	£36.99

[2] *'kWe' = kilo Watts of electrical energy and 'kWt' = kilo Watts of thermal (heat) energy*

[3] *Refer to The John Nix Farm Management Pocketbook www.thepocketbook.co.uk for more detail.*

[4] *The Office of Gas and Electricity Markets*

Year*	***Renewables Obligation Target*** *(of total electricity output)*	Non-compliance Penalty per ROC
Annually	+1 %	Index Linked
to 2015/16	15.4 %	Increments
The RO year is 1st April to 31st March		

Recycling the buy-out fund back to those companies that hold the ROCs has two implications. It makes the RO more compelling to companies because, whilst paying £36.99/MWh might be a cheaper option than investing in a renewable sector of the business, that money would be redistributed to competitors. Also, as ROCs are tradable, the market value of ROCs is higher the further away the industry is from achieving its aggregate target for the year.

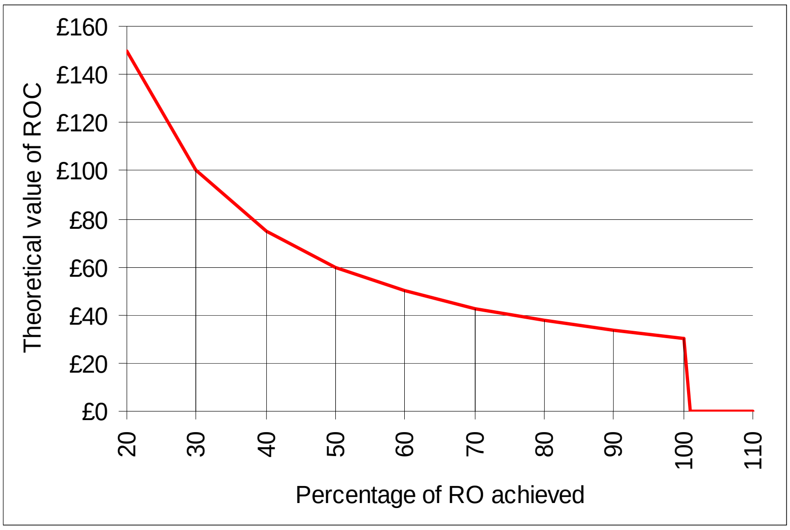
For example, say for simplicity, 1,000 ROCs are required to meet the RO. In example 'A' in Table 4, 800 ROCs are not met so £36.99 is paid on each one making a buy-out fund of £29,592. This is then redistributed equally to the 200 ROCs allocated to those who did incorporate renewables, making a payout rate of £147.96 each, a worthwhile additional reward for the production of renewable electricity. However, if only 200 ROCs are missed as in example C, the fund is £7,398. This is divided equally amongst the 800 ROCs, meaning each receives only £9.25.

Table 4 ~ National Effect of Missing RO on ROCs (2010/11)

	ROCs	**'Buy-out' penalty**	**Total 'Buy-out' Fund**	**Payment per ROC**
Example A	800 without ROCs	£36.99/ROC	£29,592	
	200 with ROCs			£147.96/ROC
Example B	500 without ROCs	£36.99/ ROC	£18,495	
	500 with ROCs			£36.99/ROC
Example C	200 without ROCs	£36.99/ ROC	£ 7,398	
	800 with ROCs			£9.25/ROC

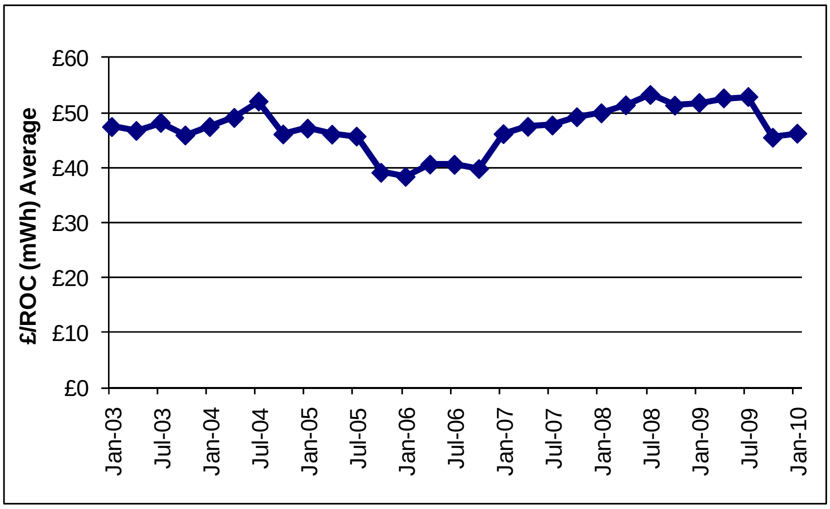
Clearly, when a licensed electricity supplier holds a ROC, it not only provides the opportunity to benefit from the buy-out fund, but also means it does not have to pay into the fund in the first place. It will therefore save the company £37. Thus the trading value of the ROC is £37 plus the likely redistribution per ROC shown in Table 4 until the annual renewable target is hit. This is calculable and illustrated graphically in Chart 1. This is a guideline as seasonal variations, ROC banking (carrying ROCs over from one year to another) and other trading risks affect their value.

Chart 1 ~ Relationship between National RO Achievement and ROC Value



Licensed electricity suppliers can either generate renewable energy themselves, contract other companies to generate the electricity on their behalves, or purchase the ROCs either from another company that has exceeded its RO target or from a renewable energy generator such as a farm that does not have an obligation. In other words, a ROC is freely tradable. As farmers are not be liable for the £37 obligation, they will probably achieve more benefit from selling ROCs to a licensed electricity provider than waiting for the redistribution dividend from the buy-out fund. Recently, ROCs have been worth about £40-£50 as Chart 2 illustrates.

Chart 2 ~ Value of ROCs at Auction[5]



As a ROC is earned from the generation of 500kWh electricity (kWhe) generated from AD, such generators receive about £80-£100-worth of ROCs per MWh and the sale of the electricity worth roughly another £50-60/MWh making an income of up to £150/MWh. Clearly if the UK achieves a greater proportion of its Renewable Obligation, the value of ROCs will fall and *vice versa*.

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[5] *Sourced at* www.e-roc.co.uk/trackrecord.htm

The implementation of the ROC banding policy was initially delayed as it was thought to contravene State Aid regulations for businesses that were set up using capital grant funding from the Rural Development Programme (RDP) or other state funded capital grant schemes. This has since been resolved satisfactorily and is no longer an issue (although it is now not clear on the regulations regarding FITS). Refer to chapter 4.10 on page 64 for details on how to register for ROCs.

The RO Review

A consultation on Financial Incentives for Renewable Energies, was published in July 2009. The Government response explains the reforms of the RO as summarised below:

- The RO is to be extended to 2037
- Individual enterprises will be eligible to claim ROCs for 20 years from commissioning.
- Projects accredited from 15th July 2009 will be able to elect whether to stay with the RO system or switch to the FIT incentives.

The ROC banding policy for AD and other technologies does not appear to be available to on-shore technologies after 2013 and second ROCs to those already receiving them will not be protected ('Grandfathered') under current regulation, although this may be subject to change. Discussions are ongoing to get biomass grandfathered, so can't rule this change out.

2.4.2. The Climate Change Levy

Non-domestic electricity customers pay a Climate Change Levy (CCL). It is £4.70/MWh for 2009/10 and is index linked. Electricity generated from eligible renewable sources is exempt. Climate Change Levy Exemption Certificates (LECs) are issued to certified renewable electricity generators, one for every MWh eligible renewable output generated. If this electricity is then used by a non-domestic customer, it negates the Climate Change Levy. LECs are only used to identify electricity that is levy exempt. AD operators can register for these certificates so their customers can claim the levy exemption.[6]

2.4.3. The Renewable Transport Fuel Obligation and Excise Duty Reductions

The RTFO, administered by the new Renewable Fuels Agency, theoretically operates in a similar manner to the RO whereby a penalty is paid by an obligated road fuel supplier that doesn't incorporate biofuels into its annual sales at its pre-determined target level. Those who do achieve target incorporation receive a pro-rata share of that fund.

A certificate is awarded for every litre of biofuel that is sold as road-fuel throughout the UK or for every kg of gaseous fuel. Methane, weighing 716g/m^3 at standard temperature and pressure, requires 1.4m^3 per certificate. Companies that supply 450,000 litres per year of fossil-based fuel have an obligation to either meet a minimum inclusion rate in their sales or pay a buy-out charge (of 15ppl per year until April 2010 then 30p thereafter). Again, this charge is intended to be recycled. To date, the RTFO has been of no value to small scale producers as the targets have been met meaning the certificates are effectively worthless. No obligation is placed on suppliers of natural gas for road transport use.

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[6] *Read more at www.cclevy.com/cclrateincrease09.html*

Excise duty on biogas as of February 2010 is 22.16p/kg. This is equivalent to an excise duty reduction of 40.88ppl from duty payable on ‘conventional’ mineral based fuels. This is guaranteed until Budget 2012. The excise duty discount on liquid biofuels will be removed in 2010. In its place, the buy-out price in the RTFO will rise from 15ppl to 30ppl.

The RTFO Review

The RTFO is to be reviewed. The Government claims it will be consulting on planned changes to the RTFO in early 2010. Changes will be implemented in December 2010.

Amongst other changes, the RTFO is to start supporting renewable fuels according to their levels of carbon savings. One of the aspects of the policy that requires attention is its calibration. When a policy fund is based on a fuel’s carbon saving, the various methods of measurement become critical. Different fuels have different ratings and vary enormously according to how they are measured.

2.4.4. Landfill Gate Fees and Tax

The volume of waste produced in the UK has been increasing by 3% per year. Since the implementation of the European Landfill Directive, local authorities are under pressure to stop this rise. Incineration is the second largest waste disposal method but is significantly dearer than landfill. Sending waste to a landfill site incurs a gate fee. This includes a Landfill Tax, the cost of which is laid out in Table 5 for ‘active’ wastes. Disposing of waste through an AD operation is cleaner and more environmentally sensitive than landfill or incineration.

Table 5 ~ Landfill Tax Escalator

Year*	Landfill Tax (£/tonne)
2007/08	£24.00
2008/09	£32.00
2009/10	£40.00
2010/11	£48.00
2011/12	£56.00
2012/13	£64.00
2013/14	£72.00

* *The Landfill tax year begins April*

2.4.5. Landfill Allowance Trading Scheme (LATS)

The Landfill Allowance Trading Scheme (LATS) is designed to reduce the amount of biodegradable organic waste from landfill to other forms of treatment as required by the Landfill Directive. Each waste disposal authority has an ‘allowance’ of how much can be disposed into landfill. In 2010 this is 75% of that land filled in 1995, 50% in 2013 and by 2020 will be down to 35%. Authorities can buy allowances from other authorities (hence the Trading Scheme) or use banked allowance from a previous year. Failing this, they will be fined £150/tonne of biodegradable waste being land-filled.

2.5. FORTHCOMING GOVERNMENT POLICIES

The UK Energy Act (November 2008) implemented the legislative aspects of the 2007 Energy White Paper ‘Meeting the Energy Challenge’. The legislation:

- Strengthened the Renewables Obligation (as above) with ROC bandings to allow greater roll-out of the renewable sector in the UK
- Allows Government to introduce Feed-In Tariffs for low carbon electricity projects of up to 5MW from April 2010 (see below).
- Enables the Government to establish a financial support mechanism for the provision of renewable heat, the Renewable Heat Incentive, (RHI) from April 2011 (also see below).

In July 2009, there was a series of government publications made. These included:

- **The UK Low Carbon Transition Plan** lays out the UK's plan to reduce carbon emissions by 18% on 2008 levels by 2020.
- **The UK Renewable Energy Strategy** explains how 15% of the UK's energy will come from renewable sources by 2020.
- **Consultation on Renewable Electricity Financial Incentives** explains the Government's ideas for Feed-In Tariffs and the Renewables Obligation.

They are available at www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx. The response to the consultation is now published and available at www.decc.gov.uk/en/content/cms/consultations/elec_financial/elec_financial.aspx . the key points of the documents for AD are discussed here:

2.5.1. Feed-In Tariffs (FIT)

Feed in Tariffs (FITs) are minimum guaranteed payments for the production of renewable electricity, used widely throughout Europe as a direct subsidy to encourage its generation. They are referred to by Government as 'clean energy cash-back'. FITs will be introduced in Great Britain (Northern Ireland will be doing its own thing) as of the 1st April 2010 to incentivise the generation of renewable energy for household, community and small business levels. FITs should be easier to administer than ROCs and therefore be more accessible to non-professional electricity generators. The Renewables Obligation will continue to operate beside FITs for professionals in the energy sector. No generator will be able to claim both FITs and ROCs. FITs will be available to several technologies providing renewable electricity, including solar, photovoltaic, wind and AD.

Feed in Tariffs will be available for projects (single technology types) of up to 5MW capacity. Above that the RO policy will remain, but there are no AD plants in the UK of this size as yet. Below 50kW capacity, the RO will be unavailable, meaning the FIT will be the only support system available. Again, there are very few AD plants in the UK so small other than a few experimental plants. So for the vast majority of AD plants, there will be a choice to be made between RO and FIT. Generators will only be able to choose once before they start receiving ROCs or FITs.

How they Work

The benefit to the producer of renewable electricity (the generator) is broken down into three main parts:

1. The Generation Tariff
2. The Export Tariff

3. The ability to offset current electrical purchases.

A generator will be paid a fee simply for generating electricity from a renewable source. It makes no difference who uses it or where it ends up, indeed, even if the generator is not linked to the National Grid. This is called the Generation Tariff. This Tariff will vary according to types of technology and capacity of plant, thereby encouraging small scale electricity generation. For AD plants with a capacity of 500kW or less, **11.5p/kWh** will be payable, those over 500kW capacity will receive **9.0p/kWh**.

On top of that, an Export Tariff of **3p/kWh** will be payable for electricity exported to the National Electricity Grid (this is the Feed - In bit). Generators will be able to opt out (or back in) from this tariff to sell into the open market (via a power purchase agreement) if they feel they can attract a higher payment from direct sales of the electricity. They will be able to make this decision annually. It remains to be seen how the market will react because, the open market value of renewable electricity has recently been exceeding 3p/kWh before claiming ROCs. It appears from the FIT documentation available so far, that the ability to claim CCL benefits will be unaffected, indicating that there could be a small additional uplift.

Table 6 Generation and Export Tariffs for FITs for AD

	Generation Tariff p/kWh	*Export Tariff p/kWh*
≤ 500kWe capacity	11.5	*3.0*
> 500kWe capacity	9.0	*3.0*

Both Tariffs will be index-inked to Retail Price Inflation, changing on 31 December. They will be payable for 20 years from starting to claim them. The rates are set with the intention of being able to generate a financial return of 5-8% for well sited installations.

The third benefit is simply that any electricity that a generator produces can be used to offset the generator's own requirements, thereby replacing imported electricity (retailing at 10-14p/kWh) with home produced (which would otherwise be saleable through the Export Tariff at 3p/kWh). For private households, income from FITs (and expenditure saved) will not be taxed, but it appears that electricity used for business purposed will be taxed in the normal way.

Both the Generation and the Export Tariffs will be paid by the generator's chosen electricity supplier. Large suppliers (those with over 50,000 domestic customers) will be obliged to participate, smaller ones having the option. At the end of every year, a 'levelisation process' will take place to ensure no individual company has paid a disproportionate amount of tariff, disadvantaging them from competitors. This cost will then be passed along to electricity consumers through higher electricity costs. This will have the effect of discouraging electricity consumption.

Capital Grants: The policy consultation, published in July 2009 clearly stated the intention not to allow capital grants to be awarded by state bodies for enterprises which were then going to claim FITs. The response has watered this statement down considerably, stating "eligibility for FITs… will be monitored on a case by case basis". All RDPE grant applications are monitored on a case by case basis already so this might imply grant applications aught to be able to continue.

There will be a central accreditation and registration system, overseen by OFGEM. The generator will become registered through the electricity supplier they choose to deal with. Each will have their own procedures, subject to minimum standards such as quarterly payments. Whereas the RO requires CHP generators to conform to the CHPQA standard, there is no mention of this in the FIT documentation. We await a publication from OFGEM on the detailed guidance for the FIT scheme. This should lay out the procedures for registering for and receiving the tariffs.

2.5.2. Renewable Heat Incentive (RHI)

There is currently no policy incentive to generate heat from renewable sources. This is despite heat accounting for 48% of all UK CO_2 emissions and 60% of domestic energy bills. The value of heat is usually low (possibly 1-2p/kWh thermal energy) which rarely justifies the capital expenditure in the UK of harnessing heat or generating it from a renewable source (the cost of natural gas to domestic consumers is 6-8p/kWht). The RHI will change this in Great Britain (again Northern Ireland might do their own thing) with its introduction proposed for April 2011. A consultation document published in early February 2010 indicates the policy will be available for a range of renewable heat technologies including injecting biomethane into the National Gas Grid, use of biogas for heat and renewable combined heat and power (including from AD) and heat for district heating systems. Tariff levels are proposed to provide a rate of return of approximately 12% on investment, higher than for FITs. It will remain open to new projects until at least 2020.

For most small scale generators (up to 200kW for AD) the payment will be ‘deemed’. This means the amount of heat produced will be estimated rather than measured, so not to encourage generators to produce more heat than they require (then leave the windows open). Regarding AD, the implication is that sub 200kW, the biogas is generally used for heat generation alone, not CHP, and the proposed tariff is 5.5p/kWh for 10 years. The consultation does not make comments about how to treat heat from CHP so makes no suggestions regarding AD above 200kw (which is almost all of them). The proposed tariff for biomethane injection into the National Gas Grid is metered at 4p/kWh, index linked annually. The consultation closes on 26th April. We will then have to wait for the response to the consultation to find out how it will affect most AD plants.

2.6. Policies In the EU and Elsewhere

Table 7 below summarises some of the national policies that have encouraged farmers/businesses within the EU and elsewhere to consider AD.

Table 7 ~ Policies to Encourage AD

Country	Policies
Denmark	• Law prohibits land filling of organic matter, must be recycled or incinerated • Taxes on incinerated organic matter are high • 20-50% capital investment subsidy has been available (now closed) • Law mandates a minimum electricity price generated from AD • Low interest loans for district heating systems

Country	Policies
Germany	• Minimum price subsidy for electricity and heat use (FITs) (c12-13 p/KWh, for 20 years) • Investment subsidies • 1993 ban on non-treated wastes to landfill • 2001 ban on combustible waste to landfill
France[7]	• 2002 ban on land-filling non-residual wastes • 2006 basic tariff according to electrical capacity, (<150kW = €110/MWh, >2MW = €95/MWh (linear interpolation in between) • Efficiency bonus of €30/MWh therm for over 75% (heat used) is paid • Bonus for production from AD is paid (€20/MWh)
Sweden	• 1996 ban on non-treated municipal solid wastes to landfill • 2002 ban on combustible wastes to landfill • 2005 ban on organic wastes to landfill
Austria	• Feed in tariffs, but only for plants built before 2006
China	• China's National Rural Biogas Construction Plan – to make 20% of farmers biogas users by 2010 • National 11th 5-year plan – to increase the treatment of MSW[8] after collection to 60%
USA	• Minimal central policies, local planning incentives

Table 7 shows the predominant legislation in the EU encouraging AD is landfill bans and objectives regarding the land filling of organic waste. Germany has had the largest incentives for AD development, with guaranteed payments of approximately 12 p/kWh of electricity put into the national grid and use of heat. The UK's double ROC policy makes returns from AD even higher in the UK. This indicates that the dramatic rise in numbers of sites in Germany over the last 8 years could be about to happen here.

The implementation of ROC banding, doubling the support for electricity generation from AD has pushed the UK to the top of the list of EU countries for financial benefits supporting AD. FITs will provide support that is easier to claim. Furthermore, with plans to implement RHIs as of April 2011, the UK's AD financial incentives will widen to include more than just electricity generation. Indeed, CHP from AD could become eligible for both supports. If these two policies are implemented as planned, the UK will see a roll-out of an AD industry on the scale that Germany experienced. DEFRA'S Shared Goals report on AD (February 2009) states its vision of having 1,000 farm based AD plants by 2020. The author if this report believes the figure could be considerably higher.

Beyond the EU, the concept of AD is growing. In the USA, whilst some of the largest examples of on-farm AD are to be found, there are only slightly more than 130 plants. Furthermore, little government support is provided. Owen Yeatman[9] reports from his Nuffield Scholarship that most US AD operations are built to

[7] *www.biogas-renewable-energy.info/biogas_income_electricity.html*

[8] *MSW – Municipal Solid Waste*

[9] *Yeatman O: The Profitable Use of Anaerobic Digestion on UK Farms. November 2007*

remove odour problems or to facilitate planning applications. The relatively low price paid for electricity in the US means most generators have lower performance than throughout the EU.

2.7. How Big is the AD Industry?

2.7.1. Current UK AD Industry

Much has changed throughout the UK AD industry since the first Edition of this report. The Government has thrown its weight behind the development of an industry by not only developing the Feed In Tariffs and Renewable Heat Incentives, but also providing support for the AD Task Force, the AD Implementation Plan and the recommendation that an AD Portal be set-up, which the NNFCC has delivered (www.biogas-info.co.uk/). The number of AD plants is growing quickly, and some suggest there are currently as many AD plants in development as there are operational indicating numbers could double within a year or 18 months.

In the UK, AD is a small but growing sector of the fledgling renewable energy industry. There are a few technology provider businesses that have been operating within the UK for several years developing and managing AD plants, but the number has doubled in the last 2 years, bringing German and other countries' experience and technologies with them. These new arrivals tend to be orientated towards larger AD plants (500kW e and over). As of December 2009, there were still few AD operations in the UK registered with OFGEM for ROCs. Table 8 does not illustrate the full list of AD operations, but those claiming ROCs from producing renewable electricity.

Table 8 ~ Organisations registered for and Claiming ROCs from AD

			ROCs Issued				
Generator Name	*Type*	***Capacity kW***	*Apr-Aug '09*	*2008/09*	*2007/08*	*2006/07*	*2005/06*
Bedfordia ~ Twinwoods Bedfordshire	Farm	**786**	3,248	4,162	2,251	429	
Mauri Products Hull	Non-Farm	**850**			1,731	728	
BioGasK Turiff Aberdeen	Farm	**340**	2,014	2,058	1,214	1,310	
Creed Park Lewis	Non Farm	**237**	230	47	0		
Holsworthy Biogas	CAD	**2,696**	10,679	10,331	9,907	10,186	6,340
South Shropshire Biowaste	Non Farm	**200**	246	482	420	24	
Wanlip AD plant Leicester	Non Farm	**1,434**	4,202	1,955	1,576	1,224	157
Smerrill Generating Station Cirencester Dairy	Farm	**300**	598	179			
Lowbrook Dorset	Farm	**365**	494	853			
Mellington Cow Power Montgomery Wales	Farm	**100**	81	61			
Total		**7,308**					

Source OFGEM

The number of plants registered by OFGEM and receiving ROCs is small as the above table illustrates. According to their information supplied, only 5 truly on-farm AD plants are claiming ROCs. Not only has the number of technology and service providers risen sharply in the UK, but with the expansion has come a rise of interest in AD from various sectors including entrepreneurs, academia, government and allied industries such as consultancy firms, electrical engineers and CHP providers. Selecting partners with suitable experience is important. The development of feedstock supply networks is slower and still regional, although digestible waste is now being seen in a new light as a resource and opportunity rather than as a liability.

The previous edition of this report included a map of known UK AD plants. This is now of little use as the numbers have risen sharply, to over 30 operational and plants (excluding water companies) and it appears there are about 75 in the development and construction stages. However an interactive map of AD plants is available on the AD Portal, at www.biogas-info.co.uk, see the link on the right hand side. It provides a very useful guide of the location of most plants.

2.7.2. Current Global AD Industry

Table 9 presents the number of AD plants and their electricity capacity in the countries continents that are most advanced in using AD. Throughout Europe, Germany accounts for approximately 85% of all farm based installations and about 75% of the total electricity produced from AD illustrating that the average German AD plant is smaller than most in Europe. Austria, Denmark and Italy have the largest plants. This is evident in Denmark where larger centralised anaerobic digestion (CAD) plants (several farmers feeding into a single digester) are prevalent. Belgium has a small number of facilities, but they are huge!

The typical German model is based on manure and harvested ensiled energy crops (predominantly maize silage). This model is appearing in the UK, the first being Owen Yeatman's in Dorset. New plant commissioning slowed in Germany in 2008 as farm commodity prices soared. Some technology suppliers experienced financial difficulties. Now they have fallen, the economics of biogas is more favourable again.

Table 9 ~ Global AD Capacity

Country	Agricultural AD plants	Installed Capacity (MWe)	Average Capacity MWe / plant
Europe			
Austria	309	69	0.22
Belgium	6	12.3	2.05
Denmark	60 farm & 20 CAD	40	0.5
France	5 farm	n/a	big
Germany	c4,000	c650	0.16
Great Britain	**c 32**	**c14**	**0.44**
Ireland	5	0.2	0.04
Italy	80	62	0.78
Netherlands	12	3.8	0.32
Switzerland	71	n/a	n/a
Sweden	7	n/a	n/a
Total Europe	**c4,600**	**~850**	**~0.19**
China	> 30 million	n/a	Very small
India	> 4 million	n/a	Very Small
USA	135 farm	n/a	n/a

Source: DEFRA – UK Biomass Strategy 2007 / Anaerobic Digestion Community, 2007

France: www.biogas-renewable-energy.info/anaerobic_digestion_fields.html

Germany: www.borda-net.org/modules/news/article.php?storyid=126.

USA: www.pewclimate.org/node/6958

China *www.chinadaily.com.cn/bizchina/2009-07/20/content_8449200.htm*

India, China and other developing nations including Vietnam, Bangladesh and Cambodia have had small-scale facilities for years and numbers continue to increase. Asia accounts for approximately 95% of the world's AD capacity, predominantly providing heat and power on a subsistence basis. Clearly, a small AD plant in a rural location, which has poor infrastructure, no electricity or sewage facility could provide major benefits to a community, providing cooking/heating fuel and fertiliser at the same time as providing a reliable form of sanitation. By the end of 2004, 15 million households in China had an AD facility. By the end of 2008, biogas was being used for heating, lighting or cooking in over 31 million households in China. These small units ($10m^3$) cost around £100 each with a 75% grant from central government.

3. TECHNICAL BRIEFING

Chapter Summary

- AD is a natural, relatively simple process that man has harnessed.
- There are many types and designs of AD suited to different situations.
- Farming can provide several feedstocks as can the food supply chain and a few other sectors.
- Biogas can be used for several purposes, electrical production being usual in the UK.
- Digestate has a fertiliser value.

The concept of anaerobic digestion is very simple, put a load of organic matter into a warmed airtight container and leave it for a few days. The microbes in the matter will digest the (non-cellulosic) feedstock releasing carbon dioxide (CO_2) and methane (CH_4). However, it is more complex than that if the operator is to achieve an efficient performance from the digester.

3.1. THE CHEMICAL PROCESS

AD has four biochemical phases:

- Hydrolysis
- Acid Fermentation
- Acetogenesis
- Methanogenesis.

Hydrolysis is the process that breaks down the long chain carbohydrates and other feedstocks into simpler soluble organic compounds (such as glycerol). This is the step in AD that takes longest so determines the retention time. Bacteria then break the compounds down into Acetic acid, either directly (**Acid Fermentation**) or via propionic butyric and long chain Volatile Fatty Acids (VFA) (**Acetogenesis**), with hydrogen and carbon dioxide also released. The hydrogen then binds with carbon molecules released from the acid digestion to make methane (**Methanogenesis**). If oxygen becomes available at this point, the hydrogen and carbon would bind to it making water and carbon dioxide rather than methane. Making all this happen in a controlled way to maximise output is where the skill of the AD manager is important. This takes place over a period ranging from about 6 to 60 days known as the 'retention period'. The total reduction of feedstock volume can be small (normally 4-8%), especially for wet systems as the water remains. However, the amount of organic matter will fall having been converted into methane and carbon dioxide. The actual amount will depend on its 'digestibility' and the plant efficiency.

Biogas is the name given to the mixture of gases produced from the process of AD. The mixture of primarily methane (CH_4) at about 60%, carbon dioxide (CO_2) at about 40% and other minor gases (mostly hydrogen sulphide and ammonia) does vary according to AD type and feedstocks. Biogas can be used unrefined to produce electricity in a generator, but not for road fuel production or as a natural gas alternative. It can be 'upgraded' through a range of cleaning and scrubbing processes to remove the CO_2

and other contaminants. The pure methane (c97%) is then known as bio-methane. It is a renewable natural gas and can be used for all the things that natural gas is used for such as heating, cooling, fertiliser production etc. Refer to chapters 8 and 9 on pages 103 and 107 for discussions.

3.2. TYPES OF AD

AD systems can be classified in several different ways:

- By temperature; Mesophilic (25-45oc) or Thermophilic (50-60oc)
- Wet (5-15% dry matter) or dry system (over 15% dry matter)
- By procedure; continuous flow or batch system,
- By number of digesters; single, double or multiple.
- By layout; vertical tank or horizontal (plug flow)

The most suitable AD system will depend on the feedstock mix and the most important output. Variables affecting which type of digester will be most suitable include:

- Variations of different feedstocks and volumes
- Capital available
- Space available
- Existing infrastructure
- Value of respective outputs (gate fees, electricity etc)

The AD Calculator Tool available with this report can provide guidance with all types of digester. The principles of AD are the same regardless of system or feedstock but the variables are likely to change. For example, a multiple digester will achieve higher digestion but have substantially higher capital costs, thermophilic digesters have shorter retention periods but raising operational and management costs. Default values assume wet, mesophilic, continuous flow digestion, but by changing the retention period, operational data and capital structure, the tool is suitable for all other technologies.

The majority of operators will be looking to maximise the production of gas per day. Some will be focussed on maximising gate-fees.

3.2.1. Mesophilic or Thermophilic

Table 10 ~ Comparison between Mesophilic and Thermophilic Digestion

	Mesophilic	Thermophilic
Temperature	25-45 ^{o}c	50-60 ^{o}c
Digestion period	18-60 days	8-18 days
Gas production /unit feedstock	Slower	Faster
Space required /unit feedstock	More	Less
Pathogen Kill	Good	Better
Management requirement	Lower	Higher
Capital Cost per m^3 capacity	Cheaper	Dearer

	Mesophilic	Thermophilic
Operating Cost	Cheaper	Dearer
On Farm	Far more common	Less likely

Mesophilic digestion operates within a temperature range of 25-45^{o}c. The feedstock is digested for a period of generally 18 to 60 days. Biogas production is slower per unit of feedstock, per day than for thermophilic digestion.

Thermophilic digestion operates at between 50-60^{o}c. The feedstock is digested for a shorter period of 10 to 18 days, meaning throughput is greater so to digest a similar amount of feedstock, a smaller digester is required. Gas production is faster per unit of feedstock and per cubic metre of digester, and a greater pathogen kill is achieved making the digestate more sterile. This system is more expensive and uses more energy to operate it, requiring warmer conditions. A greater level of operating management is required. In most farm systems, this greater cost doesn't seem to yield a sufficient additional return of marketable products. All on-farm AD systems in the UK to date are mesophilic to our knowledge. Thermophilic digesters are understandably more cost effective in hotter climates.

3.2.2. Wet or Dry

Table 11 ~ Comparison between Wet and Dry Digestion

	Wet	Dry
Dry Matter	5 - 15%	15% to 50%
Gas production /unit feedstock	Lower	Higher (more dry matter)
Space required	More	Less (depends on system)
Feedstock digestion	Less volume reduction	More volume reduction
Operating Cost	Dearer	Cheaper, less water to heat
Maintenance	More moving parts	Fewer moving parts, but must be much stronger
Digestate	More water effluent	Less water to store
Set-up capital cost	Lower	Higher
On Farm	Handles slurry not straw	Handles stackable feedstock
Suitability	Ideal for slurry & vegetable waste	Ideal for drier silages & straw based feedstock

The difference between 'wet' and 'dry' AD is only about 10% moisture. What that difference means, is that wet AD can be treated as a liquid with solid in it so it can be pumped and stirred. 'Dry' AD can be shovelled and augured; this is still a very wet consistency usually in the region of 75-85% moisture, like sludge (so not actually dry by a long way). A well chopped silage can operate as a sole feedstock, suitable for a dry fermenter. Mixed with slurry or other wet feedstocks it becomes a wet feedstock. Examples of other wet feedstocks include slurry, and vegetable wastes (we note that tomatoes have a lower dry matter than milk). With a 'dry' system, there will be less water to heat, so thermophilic systems are more likely to be dry than mesophilic systems; the proportion of biological matter will be higher thereby enabling a higher gas yield per cubic metre of digestate.

There is a fixed minimum amount of energy in every feedstock. Different systems will extract this at different rates. However, if left in the digester long enough, all systems will extract about the same amount of energy. It is just a matter of how long the retention period is; the longer it is, the slower the turnover of feedstock, making the plant more costly to operate. The dry matter figures are of the feedstock as it enters the digester. As it digests, organic matter breaks down, some becoming biogas. Its fluidity therefore rises substantially.

3.2.3. Continuous Flow or Batch Systems

Table 12 ~ Comparison between Continuous and Batch Systems

	Continuous	Batch
Gas production /unit feedstock	Usually higher	Lower
Operating Cost	Cheaper	Dearer
Management requirement	Lower	Higher
Set-up capital cost	Lower	Higher
Feasibility on farm	Higher	Lower
Space required	Less needed	More usually required
Level output of gas	Yes	Only if multiple digesters

The vast majority of digesters and all wet digesters are continuous flow. Removing digestate and restarting an AD system every couple of weeks, reheating the feedstock from cold, re-seeding it with inoculum and waiting for the bacteria to reach their critical mass, coupled with the effects of allowing oxygen into the digester when it is opened up provide big management issues. Some dry systems are batch based, building on the simplicity of the system. Having an issue of peaks of biogas generation, several of these digesters are often lined up with their changeover times staggered to keep the gas yield steady.

3.2.4. Number of Digester Tanks

Table 13 ~ Single or Multiple Digesters

	Single	Multiple
Gas production /unit feedstock	Lower	Higher
Space required	Less	More
Maintenance	Lower	More working parts
Management requirement	Lower	Higher
Capital Cost	Cheaper	Dearer
Operating Cost	Cheaper	Dearer

Page 23 explains how AD has four biochemical stages. Each has slightly different optimum conditions such as pH. Some AD systems take advantage of this by using secondary digesters to meet those conditions. As a result, higher gas yield per cubic metre feedstock can be achieved in a shorter time, but in return more operating costs and management are required with a greater set-up capital requirement. Most UK farm systems at the moment are single or double stage digesters.

A multiple digester is likely to yield a higher amount of gas per unit of feedstock because it is likely to be more fully digested. The Somerset based Organic Power[10] has developed a system whereby the feedstock passes through 8 tanks before leaving the system. This system would make the system efficient in terms of gas production per unit of feedstock but possibly less so in terms of gas production per pound invested.

3.2.5. Vertical Tank or Horizontal Plug Flow

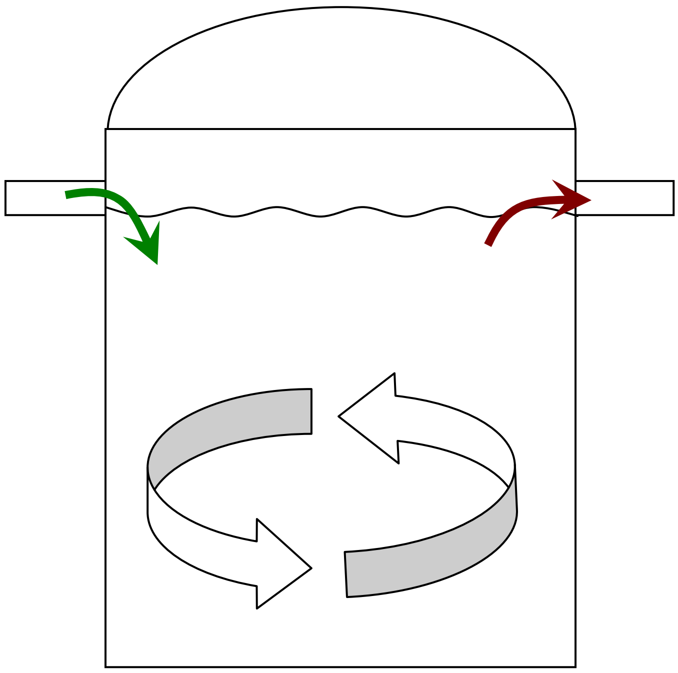
Table 14 ~ Vertical Tank or Horizontal Plug Flow Comparison

	Vertical Tank	**Horizontal Plug Flow**
Frequency	More Common in UK	Rarer
Benefit	Simple and cheaper to operate	All feedstock in for same time

Most (wet) digesters are vertical towers, taking feedstock in through a pipe on one side with digestate overflowing through a pipe on the other. Some lay horizontally. In this case, a more solid texture can be used to create a 'plug' to flow through the pipe at a speed determined by the rate it is fed. Digestate leaves from the other end. In this system, there is less chance of any feedstock leaving the digester before the correct digestion time is up or remaining in there for an uneconomically long time. Figure 3 illustrates a simple vertical digester. There is a proportion of the feedstock that will leave the digester before it is fully digested, and likewise also some that remains in there too long. This effect can be exaggerated if some feedstock silts up at the base of the tank, effectively making the digester smaller. Agitators are necessary to prevent this but some systems are more effective than others.

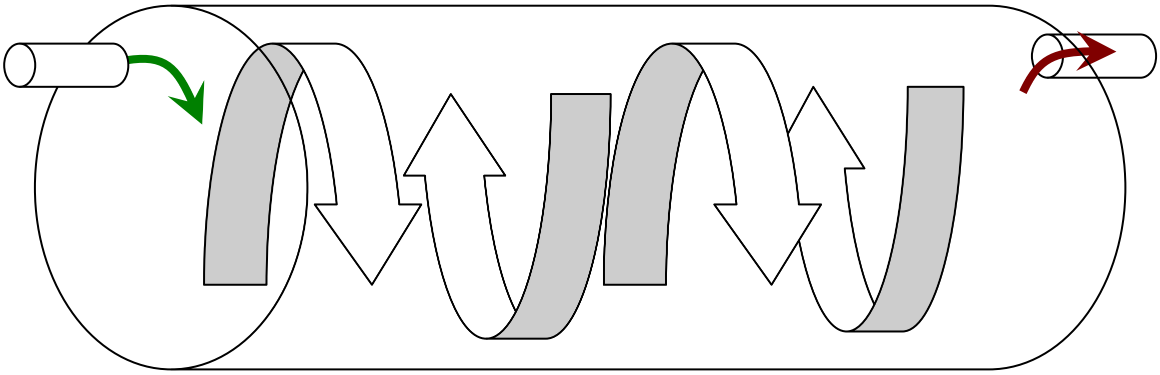
The vertical system is potentially higher and therefore more obtrusive although digesters can be partially sunk into the ground. Indeed, most of them are no higher than the digestate holding tank and usually considerably smaller.

Figure 3 ~ Cross Section of Vertical Wet Digester Illustrating Digestate Movement



[10] www.organic-power.co.uk/

Figure 4 ~ View of Horizontal Plug-Flow Digester Illustrating Digestate Movement



3.3. PHYSICAL REQUIREMENTS

An AD plant requires more than a digester. Depending on feedstock and end product use, it may require:

- Feedstock reception area
- Feedstock shredder/pulveriser/masher
- Feedstock blending tanks
- De-gritter
- Feedstock storage tanks
- Secondary digester
- Monitor and control system
- Odour retention system
- Biogas condenser
- Biogas scrubber (H_2S)
- Biogas filters
- Heat exchanger
- Combined heat and power generator
- National grid connection and meter
- Digestate storage containers
- Gas handling facilities and flare stack
- Digestate loading facility
- Digestate dewatering, such as a weeping wall, sieve separator or belt dryer
- Necessary pipes, valves and other connections
- Pasteurisation unit
- Weighbridge or volume recording meters
- Laboratory
- Administration office

In other words, there is plenty to consider. Despite all this, having an AD facility on your farm may not necessarily require much space (only 1-2 hectares for large sites and much less for small units) but its location will be important. It can be a task requiring delicate negotiating and diplomatic skills to achieve a facility that is sized and located in such a way is to please all interested parties. For example, insurers will be keen it is safely located, the Environment Agency wanting it where it cannot pollute, and Farm Assurance bodies interested in the other crops stored on farm. Several management factors will also be critical. Some plants have failed simply because of being poorly located.

3.3.1. Pre-Treatment

Before simply tipping a feedstock into the digester, it may require preparation. This could include:

- Chopping large pieces to prevent clogging and ease microbial digestion
- Blending feedstocks together. A correct balance of feedstock will raise the overall biogas yield and improve the consistency of the feedstock.
- Feedstock could contain grit or heavy material such as sand. This should not be allowed to enter the digester so it doesn't silt up.
- Other tasks concerning third party waste are likely. These may include weighing (for gate fee purposes), de-packaging, pasteurisation, chopping and mixing.

A well chopped maize silage and slurry should require little pre-treatment. However, most systems incorporate a mulcher of some kind to prevent straw entering the system and clogging pipes. These are usually built into the feeder pump thus preventing additional manual processes.

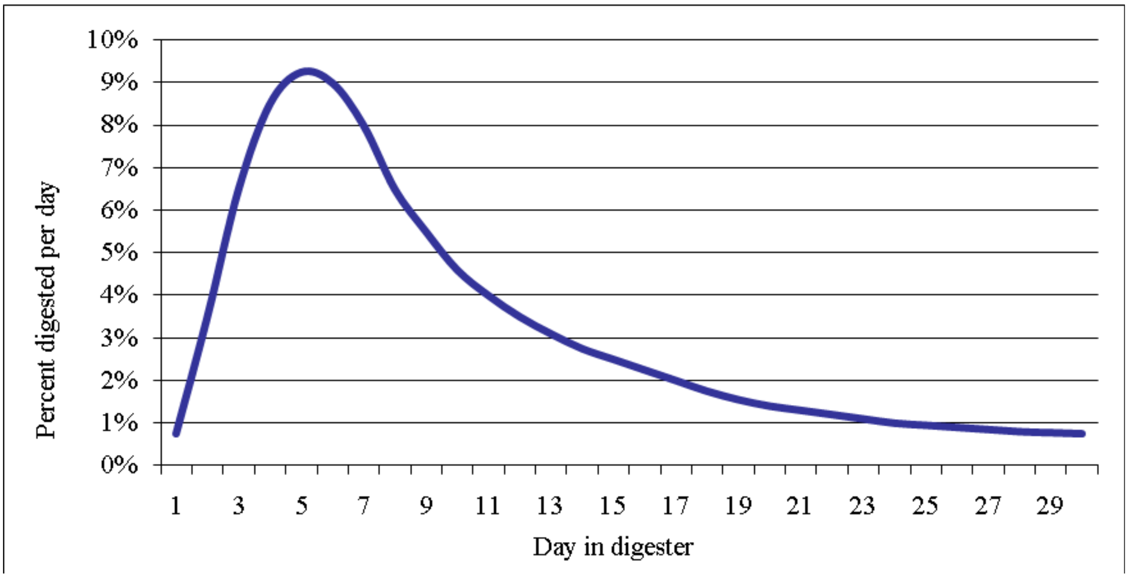
3.3.2. The Digestion Process

Digesters should be fed at least daily. Automated feeders either feed continuously from a holding bin or every 4 hours or so. In most cases, the rate at which the digestate is removed from the AD plant will be dictated by the input of new feedstock. When more feedstock is introduced, the level of total feedstock rises, and some is released through an outflow pipe. On average, the number of days the digestate remains in the digester will be the volume of the digester divided by the daily feedstock volume introduced:

Volume of digester ÷ feedstock volume per day = average number of days feedstock digested

So, to calculate the necessary digester size, take your total annual feedstock, divide it by 365 giving your daily tonnage and multiply it by the retention time. If your feedstock supply will not be regular each day, take your volume over the peak load period (the calculator will do this for you).

Figure 5 ~ Example Rate of Daily Biogas from Feedstocks

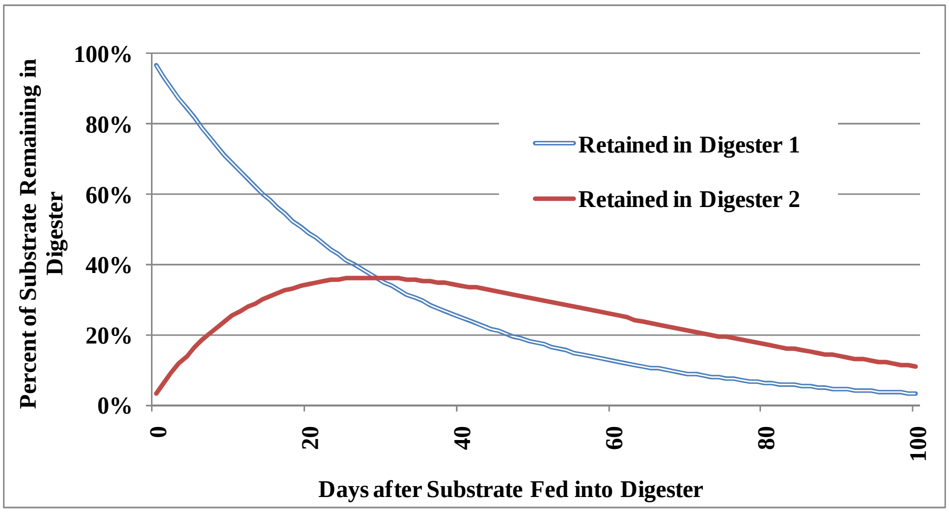


Clearly, if the digester capacity is fixed, as the volume of feedstock rises, feedstock will spend less time in the digester. Gas production from feedstock tends to peak within a few days of introduction and then tails off over a long period. The faster the throughput of feedstock, the higher the gas yield of the plant will be up to a point, but yield per unit of feedstock will fall. Operators must understand what their limiting factors are. Farmers growing energy crops may want to maximise their gas production per tonne of feedstock, whereas those with surplus feedstock (maybe from third parties) will be focussed on gas yield of the digester. In this scenario, the digestate coming out of the digester will be less digested and possibly of lower quality. From looking at Figure 5, it is clear that reducing the digestion process from 30 to 25 days in this example, would have only a minimal effect on gas yield.

3.3.3. Digester Inefficiencies

It can be seen from Figure 3 on page 27 that when feedstock enters a vertical liquid digester, it quickly mixes. When digestate is removed, unless the digester is particularly well designed, some of the newly fed feedstock will also exit whilst some remains in the digester for a very long time. This can be calculated and is shown in Chart 3. This chart tracks the movement of a single day's feedstock. It refers to a plant with 2 digesters, both with a retention time of 30 days (e.g. 1,200 cubic meter capacity per digester taking 40 cubic meters feedstock per day). It shows that after 30 days (the full retention time), a third of the feedstock fed on that day is still in the digester, a further third in the second digester and the last third removed as digestate. Clearly, this is a crude method for maximising the use of a digester. There are some designs that do not allow the feedstock to short circuit the system. After 3 days, 9.7% has left the first digester, but even after 70 days, there is still 10% remaining. This takes no account of any silting.

Chart 3 ~ Substrate Retention Patterns of a 30-day Retention Period



3.3.4. Cleaning the Biogas

Biogas contains low levels of contaminants:

- Hydrogen sulphide, which is highly corrosive and noxious. It also has a pungent odour. Various chemical and iron based systems are available to scrub this out. As it corrodes steel, it is generally removed before putting gas through generators.
- Moisture present in the gas lowers its calorific value, and reduces the electricity generator performance. The gas will pass through a condensing machine before connecting to the CHP.
- Siloxanes, silicate and oxygen based compounds. This would only be an issue from imported feedstocks from municipal or industrial waste sources.

- Other particulates may be present which could affect the wear and tear of the generator. Fine filters may be required to remove these, depending on contamination level and end use.

How thoroughly the gas needs cleaning will depend on the end-use of the gas; an electricity generator will not require the level or purification that compressed gas for motor vehicle use would need. This makes electricity generation considerably more straight forward, especially for smaller scale AD operations. For a CHP generator it is recommended to condense the water vapour from the biogas and to reduce the hydrogen sulphide concentration to reduce corrosion problems.

3.4. ON-FARM SYSTEMS

Start-up of an AD system

When a digester is first filled and becomes air tight, not only will it take several days to fill and reach the correct temperature, but could also take weeks before the correct micro-flora and bacterial cultures develop and start creating methane.

At the stage of commissioning a digester, it may not be necessary to use ‘seed digestate’ from an already functional digester (of similar type) but its availability may well accelerate the microbial activity. This would introduce the correct microbes into the tank to grow and establish. The importance of this is disputed, bearing in mind that the microbial content of most slurries (ruminant slurries especially) contain a very similar blend of microbes as required in the digestate.

Day to Day Management and Control Requirements

Ongoing checks, monitoring and supply-chain care should be maintained regularly:

- Ensuring the pH is correct
- Temperature maintenance
- Gas yield and electricity generation are meeting expectation
- Ensuring the mixing procedure is effective
- Supply of digestate to land
- Ongoing care of contracts for feedstock suppliers (if there are outside suppliers)
- Biogas cleaning performance
- Administration of electrical sales and ROCs or FITs

Once the plant is operational and the operator is familiar with the various parameters within which the variables sit, some will not need checking daily (especially for straight forward farm digesters) but the key measurables known as Critical Control Points, in particular gas production or electricity generation and digestate production, will be monitored. Any dips in these outputs would quickly indicate a problem with the ‘health’ of the plant. As a comparison, a cowman does not check every cow’s temperature each day, but if the milk yield of any dropped significantly, then he would investigate.

3.5. CENTRAL AD (CAD)

Centralised Anaerobic Digestion plants are commonplace throughout Denmark. They are very large digesters taking in slurry from as many as 80 farms in the largest of cases. The farmer suppliers are often share-holders with a financial interest in its success. As the yield from slurry is low, in order to achieve a return, other organic waste streams are also digested taken from local food manufacturing businesses or cropped. Whilst the business structure of a CAD plant is rather different to that of an on-farm digester, the technical procedures are much the same, just on a different scale. There is one in the UK at present (Holsworthy Summerlease Biogas). There are both benefits and disadvantages of a CAD structure:

Advantages of a CAD plant

- Greater economy of scale can be achieved
- Specialist management and staff can be justified
- Heat and electricity (or biogas end product) contract negotiating leverage is greater
- Far more biogas production makes alternative uses for biogas more viable
- Higher capital is required but less capital per tonne of capacity
- Less reliance on one herd of cattle, may take feedstock from several routes
- Farmer/investor's individual risk exposure is spread.
- No farmer time is required beyond coordinating manure deliveries

Disadvantages and risks of CAD

- Cost of transport; the plant will inevitably be further away from the feedstock requiring lorries to bring it in.
- It involves cooperation
- Planning consent and location will become a bigger issue
- Far greater infrastructure is required, including
  - Administration office, weighbridge, laboratory facilities, feedstock screening, loading and vehicle cleaning
  - Very tight supply chain control (both ways) especially feedstock control and timing.
- It raises the risk of disease spread and biosecurity measures require close management

3.6. MAXIMISING BIOGAS AND METHANE YIELDS

Dry Matter

Digestate comes out of the digester feeling wetter than the feedstock going in. This is chiefly because the process of digestion breaks down the cell walls of the organic material releasing the contained water. Secondly, some dry matter is converted to biogas and drawn off. Ensuring the right amount of water for the respective system is important; too dry, and the feedstock will not mix and move around the digester properly, too wet and water will be heated unnecessarily and there will be less organic matter in the tank to digest and convert to biogas.

> *Water contains no energy so yields no biogas but will be heated and stirred, costing energy if too much is included in the digestate, and will lower biogas yield per tonne or cubic meter of substrate. Yet a minimum amount is necessary for the functioning of the plant.*

Reducing a feedstock's dry matter by dilution can use considerable amounts of water. Not only would this entail the cost of sourcing the water but also of heating it unnecessarily. The biggest cost though could be the greater digester capacity, just for water. Technology companies are divided on how to achieve this. Some recirculate the digestate liquor; others claim it can upset the pH balance by making the proteins too concentrated so suggest adding water. Using mains water (at potentially £1.50 per m^3) can be costly. Other companies again have other techniques for solving the problem.

Air Tight

If the digester is not completely air-tight, not only will some of the biogas escape, but any oxygen that enters the tank will be liable to lower the percentage of methane in the biogas; a greater amount of carbon dioxide will result.

Acidity

The microbes operate best at a steady pH of between 6.8 to 8.0. Outside this range, they become less active and die at extreme pH levels. Feeding the digester too fast raises the acidity (lowers pH). Excessive high protein feedstocks can also affect the pH by a rise in ammonia within the substrate.

Carbon Nitrogen Ratio Balance

The bacteria in the digestate consume about 30 times more carbon than nitrogen (protein), but both are essential for their healthy growth (just like any other organism). Feeding the two components in a ratio of 30:1 would optimise the use of both elements, thereby raising the biogas production efficiency.

This sounds rather scientific, but in essence, the most practical interpretation of this is that any food that is of high energy level for animals (or humans) tends to be high energy for AD plants, oils and fats being the highest in all cases. The lowest yielding feedstocks are feeds that have already been digested, and therefore have had energy taken from them once already i.e. manures and slurries. These, of course, have a higher proportion of water content too.

The only problem with focussing simply on high yielding feedstocks is that at some point, the balance of energy and microbial supply, and the entire digestion process, can collapse to near zero yield if insufficient micro-flora is available to digest the substrate. Humans would get indigestion from just eating fats, so does a biogas plant.

Feed Blends

As the above three factors suggest, feedstocks can be managed in order to optimise biogas yields. Blending feedstocks can not only provide a balance between high yield feedstocks, low cost feedstocks and those useful for balancing the digestate, but also raise the efficiency of extraction of biogas from the feedstock and maximise the amount of methane in the biogas.

Changes to the feedstock composition should be made gradually in a similar manner to how new rations are introduced to ruminants to gently encourage the adjustment of microbial content. If feedstock is likely to vary much, holding tanks for blending feedstock might be required.

Freshness is important to retain the energy of a feedstock. As it starts to breakdown aerobically (compost), so the energy levels fall. Some feedstocks such as poultry litter decompose faster than others. It is also important to note that the proportion of methane in the biogas will vary according to the feedstock. For example, biogas from maize silage tends to be about 55% methane, whereas the biogas from feed waste yields nearer to 60% methane. Biogas from pure fat can be as high as 75% methane[11], a third more energy than from maize silage.

Methane yield is highest from fats, then proteins and then carbohydrates. A feedstock with highest potential gas value may not have ideal other characteristics such as moisture content to enter the plant unmixed. For example, a feedstock too high in fat and protein will create foaming, making the biogas capture difficult and block pipes etc. Too much carbohydrate will decrease the methane yield in the biogas.

Time in the Digester

The AD manager has a decision to make between the turnover of the feedstock in the digester and the completion of the digestion process. If the operator has a limited feedstock or is paying for it (for example by growing energy crops) he may want to ensure full digestion and gas capture. However, if the majority of the AD plant's income is from gate-fees, then increasing the turnover of the site increases the opportunity for revenue.

Critically, the longer feedstock is retained in the digester, the larger the digester will have to be if the feed rate remains unchanged. Feeding 50 tonnes a day and retaining it for 15 days would require a digester of 750m^3, whereas the same 50 tonnes a day, retained for 50 days, would require a digester capacity of 2,500m^3. The cost of this additional capacity, not only in terms of initial capital expenditure but also ongoing heating cost, may outweigh the additional revenue of the larger capacity. This is especially the case if the additional substrate available has low energy potential such as slurry. When calculating this, it is important to consider several aspects:

- Does the substrate mixture have sufficient manure/slurry to provide the necessary micro-flora?
- What is the potential additional gas yield per additional cubic meter of capacity?
    - What is the turnover per year?
- What is its value?
- What is the additional cost of heating and operating the larger plant?
- Has the capital cost included:
    - The digester
    - The greater CHP generator if necessary
    - The digestate storage tanks and other capital items.

It is therefore not a simple decision on how big to make the plant. A calculator is available on the associated spreadsheet tool to help identify what the additional revenue required per additional cubic meter of capacity is.

Table 15 ~ Comparison of Throughput Rate of Digestion

	Slow	**Fast**
Feedstock Throughput	Lower	Higher
Gate fee Opportunity	Lower	Higher

[11] www.fao.org/docrep/T0541E/T0541E0b.htm

	Slow	Fast
Biogas yield per m^3 feedstock	Higher	Lower
Biogas yield per m^3 digester	Lower	Higher
Biogas yield per unit time	Lower	Higher
Digestate quality	Higher	Poorer

3.7. FEEDSTOCKS

3.7.1. On Farm Feedstocks

Examples of on-farm feedstock streams are:

- Slurries
- Farm yard manures
- Vegetable wastes
- Silage
- Waste milk
- Grain, e.g. that of poor quality and value elsewhere
- Wastes from other primary processing that might take place on the farm such as waste meal etc.

The list of what an anaerobic digester can digest is long. Essentially, it is any plant or animal matter that is not woody (AD cannot digest cellulose[12]). This also means wood products like paper (and cellulosic materials like straw) will slow the digester. Care over the feedstock should be taken on 3 counts:

1. What goes in to a plant determines what comes out. If feedstocks containing high levels of trace elements are regularly put into the digester, the digestate will also have high levels. Over the long term, this may be detrimental to the quality of the digestate as a fertiliser and therefore its value. It could potentially harm the land it is spread over.
2. Some chemicals are toxic to microbes and could kill the delicate balance of bacteria in the digester liquor. Examples such as;
    - bleach,
    - antibiotics and other old veterinary medicines,
    - sheep dip,
    - surplus pesticides,
    - moulds like Ergot and mycotoxin from Fusarium
    - engine oil

[12] *Being older in evolutionary terms than trees, anaerobic microbes evolved without the ability to digest cellulose (what trees are made out of).*

3.7.2. Feedstock Yields

Table 16 lays out the potential yields for each of the main agricultural feedstocks. Basic data available for expected yield varies by as much as 40%. Whilst any table of yields will be able to provide a guideline of what the feedstock is likely to yield, each will vary for several reasons including:

- Dry matter content (especially of slurry and food waste) will vary greatly
- Amount of energy in the feedstock (e.g. freshness or silage quality)
- Length of time in the digester or type of AD used, i.e. completeness of digestion
- Gas yield measured in 'standard' conditions of 0^{o}c, 1013 bars and no moisture is quite different to the volume of gas taken directly from a warm, wet digester
- Methane content of biogas varies considerably and therefore so does the energy content
- Purity of feedstock. For example crude glycerine yield may be half that of pure glycerine

However, there are some good guidelines that can be used. The most comprehensive websites detailing all the yields are a German site www.lfl.bayern.de/ilb/technik/10225/index.php; it's a good site if you can read German. Another excellent downloadable database is on the CropGen website www.cropgen.soton.ac.uk/deliverables.htm. There are other useful documents on this site too.

Table 16 ~ Biogas Output from Various Feedstocks

Feedstock	Dry Matter %	Biogas Yield m^3/tonne	Value of Biogas £/tonne*
Cattle Slurry	10	15 – 25	4.70 - 7.90
Pig Slurry	8	15 - 25	4.70 - 7.90
Poultry	20	30 - 100	9.50 - 31.70
Maize Silage	33	180 - 220	57.40 - 70.00
Grass Silage	28	160 - 200	50.50 - 63.40
Maize Grain	80	500	160
Whole crop wheat	33	185	58
Rolled wheat grain	85	610	190
Crude Glycerine	80	580 - 1,000	185 - 320
Rape Meal	90	600	190
Fats	Up to 100	Up to 1,200	Up to 380
Cattle Slurry	10	15 – 25	4.70 - 7.90

** at 14.5p/kWh electricity (post April 2010), 1p/kWh heat ~ Refer to the calculator to change assumptions*

*** Wheat (and other grains) should be rolled or cracked first*

3.7.3. Calculating the Energy in Biogas

There are 10.5kWh energy in $1m^3$ of natural gas (at 95% CH_4). Therefore biogas at 60% methane has the energy potential of 6.7kwh - The engine efficiency defines how much electricity, heat and losses there are. So a CHP with 30% electrical efficiency and 50% heat efficiency (therefore 15% losses) can produce 30% of 6.7kW hrs of electricity per cu m biogas (at 60% methane) = 2.0kWhe/m^3 and 3.3 kWhe/m^3. There will be some inefficiencies in the system too which is accounted for in the calculator.

Table 17 ~ Energy Yield from 1m^3 Biogas in a CHP Generator

	Efficiency of Conversion	**Energy Value**
1 m^3 natural gas (95% CH_4)		10.5kWh
1 m^3 biogas (60% CH_4)		**6.7kWh**
Electricity Generation at 30% Efficient	30%	2.0kWh
Heat Generation at 50% Efficient	50%	3.3kWh
Lost	20%	1.4kWh
There will be other losses elsewhere in the system; this only shows energy conversion		

3.7.4. Cost and Value of Feedstocks

The cost of feedstocks has to be calculated against their relative values; slurry is usually effectively free, grains and meals etc can be valued against their market prices, but energy crops are more complex. Unless there is a local market for ensiled crops, they must be calculated by their costs of production. This is covered on page 39. The calculation is illustrated here:

(kWhe per m^3 biogas x p/kWhe) + (2 x kWhe generation /m^3 biogas x value of ROC/kW) + (kWht generation /m^3 biogas x p/kWht) x Biogas yield per tonne of substrate.

kWhe = kilo Watt hours of electrical energy

kWht = kilo Watt hours of thermal (heat) energy

An example of the feedstock value of 1 tonne cattle slurry is as follows:

(1.9kWe/m^3 biogas x 4.8p/kWe) + (2 x 1.9kWe/m^3 biogas x 4.9p ROC/kW) + (2.5kWt/m^3 biogas x 1.2p/kWt) x 20 m^3 Biogas yield per tonne of substrate.

(1.9kWe x 4.8p) + (2ROC x 1.9kWe x 4.8p) + (2.5kWt x 1.2p) x 20 m^3

= (9.12) + (18.24) + (3) x 20 = £6.07

Calculating the revenue potential of a feedstock can be done using the associated spreadsheet calculator.

Using FITs is simpler:

(Generation Tariff (11.5 or 9.0p) + Export Tariff or Sale Price (3.0p) x kWhe/m^3) + (heat calculation as before) x biogas yield

Clearly, a feedstock that yields maybe 10 times as much gas per tonne will be worth 10 times as much in terms of electricity and heat production. Maize silage, for example yields approximately 200m^3 biogas per tonne, giving it a biogas revenue of £54.40/tonne before production costs, overheads and value of digestate. It can be seen that maize silage therefore offers a good opportunity to generate a return on capital from biogas production. Different feedstocks incur varying burdens on overhead and capital. For example, slurry required about 15 days to digest, silage about 60 days, making it 4 times costlier to digest. It will also require more pre-treatment.

Slurry

Slurry acts as an excellent ‘balancer’, reducing the risks of foaming etc. and has an ideal blend of microbes to act as a base feedstock, keeping the balance of microbes healthy. It has a low dry matter (cattle 5-10%), and low biogas yield (usually no more than 25m^3/tonne). This biogas yield gives it a value of up to £7.30/tonne for electricity and heat with FITs plus any additional fertiliser value.

Having such a low gas yield, in order to generate enough biogas to generate significant electricity either a very large amount of slurry is required, or an additional feedstock could be used to boost the yields. Examples of this are included in the case studies. It is generally unviable to move slurry far, for example, by lorry. There are a few occasions where this is overcome (refer to Case Studies for examples), but calculations should be carefully made before deciding on this business plan.

When cattle are at grass, it is clearly impossible to collect their slurry. So unless a large slurry storage tank is erected as a feedstock holder, another feedstock should be found to supply the digester in summer months. This could be silage or green waste etc. The changeover should be carefully managed. One or two on-farm AD systems in the UK do actually close down for the summer, but this is not a lucrative choice having invested high sums of capital into the operation. Scrapings from milking parlours etc. could still keep the plant operational throughout summer months. Extending the time cows spend on concrete or other small management changes could seriously damage the performance of the dairy enterprise and be counter productive.

Straw

Clean straw is a lignocellulosic based plant material. It is therefore not very digestible and has a low gas yield. Unless it is finely chopped, it can clog up pipes, block exits and float to the top of the digester in wet based systems, making a mat, slowing gas production. It can be used in a very dry fermentation system (such as the Bekon Dry Fermentation System[13]) to bulk the feedstock into a stackable material and can be used in small proportions when it has been used as bedding and is therefore mixed with slurry making farm yard manure. Farm yard manure (FYM) contains a far greater level of available nutrients that an AD plant can digest. FYM can achieve a biogas yield of up to 50m^3 per tonne.

Glycerol

Glycerol, an oil, added in relatively small amounts is an excellent feedstock to increase gas yields considerably. Indeed, the Danish on-farm Case Study presently includes glycerol at 12% of the total ration, and accounts for half the total biogas produced. Oils have a very high gas yield (they are full of energy).

The problem might be sourcing. Glycerol demand is rising (it has over 1,200 uses, most of which can pay more than an AD plant). If a supply becomes available, it will probably be crude, meaning it still contains impurities such as methanol and sodium hydroxide which could unbalance the pH and bacterial function. It

[13] www.bekon-energy.de/english/products.htm

is used in the Danish case study imported from Sweden at a far cheaper rate than it can be bought here. Its high biogas yield (at about 850m^3/tonne) values it at approximately £250/tonne for biogas with FITs.

Energy Crops

Energy crops are those grown for feedstock. Examples are maize and grass. In order that they are available throughout the year, they are ensiled. Of course, they come at a cost having either to be purchased or grown on-farm. Their cost includes not only their variable costs but also the overhead costs such as labour, machinery, property and possibly rent and finance. Using home-grown energy crops could have considerable implications on the structure and layout of the farm business, and the relative value of the crops would vary depending on the opportunity cost of the land and other resources used to produce them.

For example, say a digester required 4,000 tonnes of silage, taking around 100 hectares on average land to produce, this would either affect on the existing rotation of the farm, require additional rented land or require contracting others to produce and supply it. If the existing rotation is arable and the first limiting factor to production is land (as it often is), the impact of reducing this resource further could be dramatic on the rest of the farm business. Alternatively, an extensive livestock farm which already has forage harvesting and ensiling equipment, could intensify its livestock by using fewer hectares (or decreasing livestock numbers), releasing land for energy crop production at relatively low cost.

Sugar Beet

One opportunity for growers in the North and West of England who lost out from the sugar beet industry restructuring might note that a high yield coupled with high sugars makes this crop potentially a good feedstock for AD. It will require fine chopping and mashing before feeding which will require energy, and also, being a root crop, operators should ensure that they are thoroughly cleaned to prevent clogging the digester with soil.

Rape Meal, Cereals and Other Feedstocks

Feed stocks such as rape meal return a high biogas yield but are expensive commodities. They are used in AD plants in varying amounts either as a short-term yield 'boost', or to utilise grain and meals that are of low value elsewhere. This might include low quality grain for example with excessive admixture. Technical experts[14] advise the use of mycotoxins/Fusarium infected wheat should be avoided as the mould, which produce antibiotics, is not healthy for the necessary microflora. Oil meals yield about 400-450m^3/tonne, giving them a benchmark electricity value in excess of £120/tonne with FITs.

Vegetable Trimmings

Vegetable processor organisations produce a large amount of trimmings and otherwise unwanted organic 'waste'. These organisations often have relatively intensive electrical requirements. They might even be located close to glasshouses where surplus heat (and CO_2) could be utilised. Vegetable trimming waste usually has a low dry matter (about 10%) and its gas yield is also relatively low (e.g. potato trimmings yield about 70m^3/tonne). However, a sufficient volume of feedstock, possibly coupled with a supply of higher

[14] *from Schmack Biogas*

yielding feedstock, provides an opportunity to become self sufficient in heat and electricity. Using default data, a yield of $70m^3$ biogas per tonne of potato peelings gives it a rough financial value of £20/tonne with FITs. Collecting unwanted by-products such as sugar beet tops can apparently reduce risks of spread of soil borne diseases. Beware not to collect large amounts of grit and soil that would clog up the digester.

This system identifies the versatility of AD. It is often assumed that AD only works in association with livestock manure or slurry, but this shows that as long as the correct decisions regarding technology types are made, then AD fits into farm systems in the Eastern side of Britain as well as the livestock areas.

Dairy Waste

Milk put through a digester has a feedstock value of approximately 3p/litre. Clearly this is low compared with ex-farm milk prices. Milk quota will be removed in 2015 and to prepare for this, quota holders are receiving extra quota to lower its value. As UK milk production is so far below quota, it is no longer likely to become a limiting factor on farms. This means that the days of simply letting milk go down the drain or onto land are gone.

In some milk processing operations, milk whey has been a waste product on occasions when prices have been very low. It has a raw value (5-6% dry matter) in a biogas plant of about £10/tonne. Presently, whey is worth far more than this. Milk excluded from the food chain because it is contaminated with antibiotics would be dangerous to feed into an AD plant. This is because antibiotics kill bacteria. Other waste dairy products would be excellent feedstocks, cheese, for example being worth around £100/tonne.

3.7.5. Non-Farm Feedstocks

Using organic residues ('waste') from third party activities can release farmland for 'conventional' cropping whilst attracting gate fees and increasing biogas yields too. Owen Yeatman in his Nuffield Farming Scholarship report[15] points out that 'this is a service that UK farmers can provide society that cannot be met by overseas competition'. He also notes that depending on which category of 'waste' the feedstock is, will depend on the potential gate fee chargeable and associated level of administration required.

In order to remain legally compliant and physically capable of handling these feedstock streams whilst meeting your suppliers' delivery requirements and also ensuring the health of the digester, some alterations to the business and physical procedures of the feedstock handling will be required. This may include:

- Pasteurising feedstocks containing animal by-product (or a chance of their inclusion)
- Weighing the feedstock for administrative and billing purposes
- Screening for unsuitable matter such as metals or packaging removal
- Holding-tanks to smooth delivery times with feed-in times and possibly to blend different feedstuffs
- A laboratory to identify the chemical contents of feedstock (fats, proteins etc) and therefore applicable feed-in rates.

[15] *The Profitable Use of Anaerobic Digestion on UK Farms November 2007*

The differences between this and an on-farm system is more to do with the business rather than the technical operation of the AD plant. Risks change as the operator loses some control of what and when the plant is fed, so managing the plant becomes more challenging. Keeping the balance of energy, microbes and so on is challenged as is the frequency of supply. Other business issues mount as connections with other companies increase and legislative administration grows.

Green Waste

Green waste, as it sounds is non-food biodegradable waste. It could be garden or park wastes such as grass clippings from a landscape gardener. Suppliers must ensure no woody fragments enter the supply.

Animal By-Products (ABPR) Waste

This is the supply of animal by-products, either directly from animals such as abattoir wastes or discarded food, with a chance it could contain meat, such as out of date food or catering waste. This has to comply with additional regulations before it can be digested. They are summarised and signposted on page 56.

3.8. WHAT TO DO WITH THE BIOGAS

There are several possible uses for biogas:

- **Heat alone** by combustion e.g. as cooking fuel: When burned, biogas generates about 2.5kW of thermal power per cubic metre (SAC). A relatively small plant is likely to generate more than most individuals would require.
- **Road fuel**: There is a very small market for compressed gas as a road fuel. The Renewable Transport Fuel Obligation (RTFO) includes biogas for road fuel but as chapter 8 illustrates, there is minimal real opportunity yet except for enthusiasts.
- **Mains gas or compressed gas**: This is happening in Germany where two plants are digesting 30,000 and 80,000 tonnes of silage to produce approaching 4 million and about 8 million cubic meters of cleaned methane gas respectively. This scale justifies the investment in the expensive gas purification plant. In the UK, RHI might make this as financially viable as electricity generation from 2011.
- Electricity production using a generator is viable but equally efficient is **heat and electricity generation using combined heat and power (CHP)** generator and is relatively straightforward. AD, requiring both, makes heat and electricity generation logical.

All of these are being done throughout Europe and Asia. In the UK, some options are more practical than others. Heat and electricity generation is considered here as the most likely and popular use for biogas. Thus, the rest of this chapter concerns the combustion of biogas in a combined heat and power generator (CHP).

3.9. COMBINED HEAT AND POWER GENERATION

CHP generators produce electricity and heat simultaneously. They are suited to AD having a substantial heat requirement itself. This makes CHP generators more attractive as nearly the same amount of electricity can be generated from a CHP generator as in a conventional generator.

In 2000, the government launched the CHP Quality Assurance programme (CHPQA). Certification enables non-domestic consumers of energy (business, commerce and the public sector) to obtain exemption from the Climate Change Levy (CCL)[16], by claiming Levy Exemption Certificates (LECs) (see Section 4.10 on page 64). OFGEM must be notified of any such power supply agreements through a CHP consumption declaration, stating that all notified electricity eligible for CHP LECs represents electricity consumed, or to be consumed. Proformas can be obtained from OFGEM[17].

To obtain a CHPQA Certificate, CHP operators must register and conduct some self-assessment procedures to ensure their CHP is 'Good Quality'. This includes measurement and recording of energy flows, prior to the calculation of Power Efficiency and a Quality Index (QI) to set thresholds. Whilst these thresholds can alter, they generally require a QI of 100 and a power efficiency of 20% (calculated from the fuel used, electricity generated and heat supplied). Each submission is then considered and if deemed suitable is validated and a certificate issued.

Enhanced Capital Allowance is available on certified CHP generators, meaning the plant qualifies for 100% capital allowance in the first year, enabling that cost to be written down against taxable business profits. Refer to Section 5.4.3 on page 74 for more information on CHPQA and how to apply for it, refer to www.chpqa.com.

Traditional coal and gas-fired power stations have an efficiency of approximately 34% and 55%, respectively, CHP plants can be up to 80% efficient[18]. This is because account is also taken of heat generated. A typical CHP unit would distribute its energy as follows:

- 30% electricity output (increased electrical output can be achieved with dual fuel engines, utilising diesel as the second fuel at about 10% of combined fuel used.
- 50% heat output (reaching up to 90^{o}c)
- 5% radiation losses from the engine
- 15% flue losses (exhaust gases)

Note larger CHP generators are more efficient than smaller ones at generating electricity. Some[19] suggest the larger (CAD scale CHPs) are between 34 to 40% efficient, with farm scale plants 20 to 32%. Heat exchangers (devices designed for efficient heat transfer from one fluid to another) are used to harvest heat from the engine block water jacket and exhaust gases. In the heat exchanger, a hot fluid (water in the engine block jacket and gas in the exhaust fumes) is used to heat a cooler fluid, which in turn becomes hot water or steam.

Making use of the Heat

The financial value of heat is determined by its subsequent use. It is less valuable than electricity, typically 1 – 1½ p/kWht (kilo Watt hours of thermal energy). The siting of the generator is not necessarily obvious.

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[16] *Under the Climate Change Levy (Amendments) Regulations 2003.*

[17] *www.ofgem.gov.uk/Sustainability/Environment/CCLCHPEx/Pages/CCLCHPEx.aspx*

[18] *Building Services and Environmental Engineer Magazine, 2005.*

[19] *Per H. Nielsen,* www.lcafood.dk/processes/energyconversion/heatandpowerfrommanure.htm

Most plants site it near the biogas plant. Some are as much as a few kilometres away as piping biogas is more efficient than piping heat to a consumer. Refer to the Danish Case Studies for examples.

This sounds fine in principle, but in practice could become complicated because, depending on plant type, size and feedstock (retention period), a proportion of the heat (ranging from 5-50%) will be required on site to heat the digester (known as the parasitic heat supply). Refer to the section on 'Utilities' on page 70 for details and figures. It is also advisable to note that, depending on what kinds of pre and post-digestion treatments and agitation procedures are adopted, a proportion of electrical energy will also be required in a similar manner. The financial costings of moving the CHP away from the digester should therefore be undertaken with real care.

3.9.1. The Power Purchase Agreement

An electricity generator does not need to be a 'licensed electricity generator' unless selling more than 50MW or have a capacity of at least 100MW, far bigger than any AD operation. There are several types of contract with which to market your electricity generation. The main examples are:

- Private wire
- Short and long term fixed price contracts
- Profiled Supply

Private Wire

Depending on contract details, electricity sold through the national grid is likely to sell for about 5p/kWh (at today's prices). Yet, because of grid costs and inefficiencies, retail prices are in excess of 12p/kWh. Finding an electricity consumer nearby, who is capable of using all the electricity generated by your plant (or indeed your own business) is likely to yield the highest return per kWh. This is because, even if the price differential between their purchase price and your wholesale price is split evenly, this should provide both parties with a real incentive to lay a direct private wire from generator to consumer.

There are several opportunities for private wires to an 'embedded third party'. Port authorities already use them and several business parks use private wires too. A good opportunity might be nearby. You will still be able to claim ROCs and LECs or the Generation Tariff but not the Export Tariff.

Whilst electricity supply in this situation is not destined to end up on the national grid, it is necessary to inform the local distribution network operator in case any does reach the network through back-feeding.

Short and Long Term Contracts

Two main types of electricity sale are short term and long-term contracts. A short term 'spill' contract is similar in concept to selling grain on the 'spot' market. It is likely to vary considerably from month to month depending on the short-term price of electricity, and may not return the highest overall price, as electricity suppliers will be using it to top up their long-term contracts as necessary.

Spill contracts may be useful whilst the AD operation is in its infancy, teething problems being solved, and highest yields reached, because penalties of failing to provide the electricity against some forward contracts can be expensive. However, most financiers will be happier with longer term fixed rates.

Most supply contracts combine electricity, ROCS and LECS at the same time. This might return the farmer a slightly lower value for the ROCS because they will be sold before the ROC year-end, and the electricity company will build in a risk and margin factor (and administration cost), but the process of electricity and certificate sales is simplified. It will also raise the incentive for an electricity supply company to take all the available electricity, even at quiet times such as at night. There are useful deals available, designed in association with major banks to combine the requirements of financiers and electricity supply companies. Some supermarkets now offer similar electricity purchase deals.

Embedded Benefits: Selling electricity to the grid from a rural location could have some benefits above the headline negotiated price. These are called 'Embedded Benefits'. As moving electricity along a wire is not 100% efficient, the further away the wire travels from the power station, the more electricity is lost from the grid. Thus, an AD operation selling to the grid in a location near the end of the grid network might offset the requirement for moving electricity long distances and therefore reduce 'distribution losses'. It is the equivalent to the 'local food' concept. On average, this could be worth ½p per kWh e.

Triads are another type of embedded benefit. Peak demand for electricity is closely monitored. Every year, normally between November and February, on particularly cold evenings, electricity demand is at its annual highest. The three highest demand peaks of the year are known as triads and all generators are operational at these times. If you supply electricity to a good licensed electricity supplier, it should tell you when this is likely to be to ensure your CHP is operational for that period. Additional money is paid, even above fixed rate contracts for electricity supply. The rates are very attractive but the time period may only be an hour or two.

Profiled Supply

Those who have the capability to store biogas, either in large low-pressure storage or smaller pressurised vessels, may be able to 'shape' their electricity profile. This means supplying electricity to the national grid when the grid most needs it at times of high demand. This is clearly day instead of night, but particularly in the early morning and early evening as people leave for, and return from work. Prices for electricity supplied only between 5.00am and 5.00pm can potentially be double those of a flat supply profile.

There are three potentially major drawbacks of signing such an agreement:

1. Biogas storage is easier said than done. The volume of storage required to hold the gas generated overnight until the morning when the electricity demand kicks in is very expensive. For a standard 400kW capacity generator, to store enough biogas (un-pressurised) for it to run for a single hour would require a tank of about 235m^3. A cylindrical tank of this volume would have to be 6 meters high with a 7-meter diameter. These sizes and costs would be prohibitive and impractical.

2. Doubling output for half the time would require a generator of double the capacity, also adding considerably to the capital outlay.

3. The risks of a profiled contract are very high. If, for whatever reason, the AD plant is at any point throughout the contract delivery period unable to supply the agreed amount of electricity, the penalties can be enormous. It is imperative for any supplier to read the small print very carefully

and calculate the risks being taken on in these sorts of agreements. Headline prices look great, but they could lead to problems.

3.9.2. Licensed Electricity Suppliers

There are providers very keen to engage with renewable energy generators, and others who appear not keen! Those wanting to engage are offering contracts with not only a reasonable headline price for the electricity but long term arrangements, administrative processing operations such as ROC administration, and assistance in some cases with the capital or connection costs. The major companies are listed here: www.electricity-guide.org.uk/companies.html and www.pastures-new.co.uk/info/basics/utility/suppliers .

3.9.3. Connecting to the National Grid

A major cost of setting up an AD plant to generate electricity is the infrastructure to harvest, move and measure the electricity produced. This cost is galling to most, as there may seem to be little of material substance to show for the investment, but the expertise and safety precautions required come at a cost.

Some suggest budgeting between 10 to 15% of the capital cost of setting up simply to this area. In reality, there is little correlation between capital outlay and connection charges, both varying from different factors. The only link is greater generator capacity adds cost to both. Whether the generator will provide electricity for a single consumer or to connect to the grid, cabling will be required along with other relevant electrical infrastructure. The cost of connection depends on two things, the setup of an electrical substation and the cabling. As a rule of thumb, the substation cost for an average size plant (500kW) is circa £50,000, plus cabling which will vary according to:

- The maximum amount of electricity you are likely to be able to supply (peak load). As electrical currents generate heat, large wattages require thicker cables. It is possible that not only the cabling to your farm would need upgrading, but others in the nearby network. This is where being a rural location, possibly near the end of a network, could push up the costs; but just think of the embedded benefits!
- All but the very smallest of electricity generators require a 3-phase connection
- The distance to a suitable connection point will vary between each situation. Booth et al (2007) suggest ½ to 1km is likely to be the limit, beyond which it will become prohibitively expensive.
- Whether wayleaves or easements are likely to be required to cross private land with objectionable landlords
- Whether the cabling is to be buried or on pylons and therefore requiring planning permission
- Whether other features have to be crossed such as rivers, railway lines or roads.
- If it is to be buried, how easy is the soil to excavate (underlying rock depth)? A minimum depth of 1 meter is legally required on agricultural land.

3.9.4. Distribution Network Operators (DNO)

The 'National' Grid is divided into fifteen areas throughout the UK. They are managed by eight different operators. These are the companies that will connect your AD plant to the national electricity grid, but they will not buy your electricity. These links provide the relevant contacts: www.r-e-a.net/info/other-news/uk-distribution-network-operators-embedded-generation-connection-contacts and www.nationalgrid.com/uk/Electricity/AboutElectricity/DistributionCompanies/

Requesting a Quote will not simply be a question of contacting the local DNO for a price. It will want detailed specifications of the electrical load and date of connection. A firm quote will not necessarily hold for long either, because if another nearby business makes a connection and uses the available load, your connection might have to be switched a long distance to the next nearest connection of that capacity. This is a 'chicken and egg' scenario because in order to know what size AD plant to build you also need to know what capacity connection is available. Different DNOs operate in different ways, some charge for provisional quotes, others don't and others again will only provide firm quotes with a charge.

Contestable and Non-contestable Works: There are things that can be done that might reduce the cost of connection. Some of the electrical work legally has to be completed by the DNO because, once the network is connected, they will be responsible for it. One such example is the actual connection process. Work that has to be undertaken by the DNO is known as 'non-contestable works'. There are other parts of the work that can be done by other electrical engineers; this part is known as 'contestable works'. These engineers have to be licensed with the National Electricity Registration Scheme (NERS). The list of these companies is available at www.lloydsregister.co.uk/ners.html. It lists the areas they operate in and proficiencies they are licensed to undertake. You can either ask them to quote for the entire work (including the fee to the DNO), or request separate quotes from the DNO and private electrical engineering company. Some of the work might be undertaken by farm staff such as trenching, but this should be agreed with the contractor in advance.[20]

3.9.5. Energy Service Companies (ESCos)

Energy Service Companies (or ESCos) are organisations that take on the total energy management for a client. Their objectives are to reduce total energy consumption by improving efficiency, reduce cost by providing alternative sources of energy and lower greenhouse gas emissions. Many take on the energy generation on their clients behalf. The development, installation and financing of arrangements is usually undertaken by the ESCo. This may involve owning and/or operating plant used to generate the heating, cooling and/or electricity.

ESCos charge a fee according to the savings in power costs made. Those who provide the energy as part of the service take on the liability for energy supply. ESCos are usually small divisions of large energy companies. Whilst an experienced energy providing company might set up an ESCo to develop customers for renewable heat and electricity, an ESCo will be too complex an undertaking for most new entrants to energy provision. Those businesses producing renewable energy and supplying customers via a private wire might be undertaking some of the roles of an ESCo.

[20] *Thanks to Smartest Energy, a licensed electricity supplier, for assistance with Connecting to the Grid and Power Purchase Agreement Sections.*

3.9.6. Business Model Options for AD

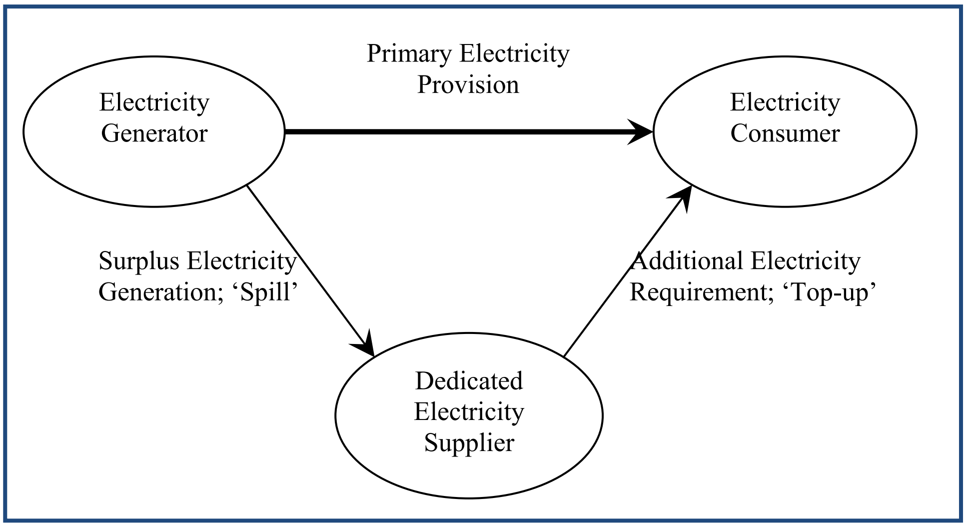
The AD operator has a product to sell. Various arrangement are possible depending on the level of retained interest. On the assumption that the end use of the biogas is heat and electricity from a CHP plant, it could range as follows:

1. The AD business owns and operates the digestion process but sells biogas to a separate company that owns and operates its CHP generator and is then responsible for the sales of heat and electricity.
2. The AD operator owns and operates the digesters and also the CHP generator to then sells heat and electricity to a separate company that becomes responsible for their provision to the end-users - this would usually be by connecting to the national grid. This might take on a commitment to produce a minimum amount and flow of electricity through a 'Power Purchase Agreement'.
3. The AD operator generates the biogas, uses it in its own CHP generators and supplies the electricity (and possibly heat) to an end user. This would normally be with a 'spill and top up' arrangement (see below) from the National Grid.

As you move through the 3 options, the potential returns increase as additional value is achievable at each point, but the liability and exposure to costly disruptions also increase. Good technical ability, sensible and close management and also clear contractual arrangements are necessary. Those looking to invest in a biogas plant should decide what their business is, where their strengths lie and what level of risk they are prepared to take on.

Spill and Top Up: A power generator and a single consumer will always have an imbalance between the power produced at any moment and that required unless the power customer is entirely flexible with its availability. Neither heat nor electricity can be easily stored (especially electricity). Any such agreement with single power consumer (or low number of them) should therefore be built including a third party; an electricity supply company as illustrated in Figure 6. This tri-partite agreement should be created so that when electricity is available from the CHP and in demand from the consumer, it is used first. If the consumer has an additional requirement for power at any time, then it can be sourced from the electricity supply company. Conversely, if surplus electricity is being produced, the electricity supply company would buy it. This is called a 'spill and top up' agreement.

Figure 6 ~ Illustration of Tripartite Electricity Contract Requirement



If a renewable energy supplier decides to engage with direct energy supply like this, it is possible they could contract with several electricity and heat consumers. These arrangements could become relatively complex with varying needs for electricity and heat provision throughout the year for different consumers, varying contractual terms and cost structures. If these arrangements become complex, then a company specialising in managing power supplies might be valuable, be that an ESCo or electricity supply company.

3.10. What to do with the Digestate

After digestion, the digestate is removed from the AD tank, and put into a storage tank. Low levels of biogas might still be produced here too as it may not be fully digested. Remember the digestate is still warm and some of the digestate will not have been in the digester for its full desired term. This gas is often collected. The volume of digestate may have only fallen by a small fraction, especially if the feedstock is of low dry matter or gas yield. Feedstocks like oils will be more completely digested.

3.10.1. Nutrient Value of Digestate

All N, P and K remain available in the digestate as none is required to make methane or carbon dioxide. The amount of nutrient varies considerably in each digestate depending primarily on the feedstock and dry matter content. An analysis of an example digestate is shown in Table 18 with a calculation of the value of the nutrients contained at recent granular fertiliser prices (February 2010).

Table 18 ~ Example Plant Nutritional content of an 'Average' Digestate

	Total Kg/M^3 *	Plant available Kg/M3	Value per m^3 Digestate
Nitrogen N	7.5	5.5	£4.90
Phosphate P_2O_5	0.3	0.2	£0.17
Potassium K_2O	2.0	1.8	£1.17
Total Fertiliser Value per m^3 digestate			**£6.30**
At granular fertiliser values of 34.5%N £225/t, 46% P_2O_5 £255/t and 60% K_2O £320/t ** Appendix D of WRAP technical report for production and use of source segregated waste (QP)*			

The raw digestate will normally have a dry matter of as little as 5% to 10% depending primarily on feedstock. It can be pumped and spread on nearby land by tank or umbilical system. However, there are restrictions on how much fertiliser can be applied to land in any season especially in Nitrate Vulnerable Zones (see page 61). A large AD operation such as a CAD, or one that makes use of non-farm feedstock streams may need more land than is accessible nearby. Refer to the associated calculator to work out the amount of land required to accommodate the volume of digestate.

Digestate has one major drawback over granular fertiliser. It is a pre-determined blend of fertiliser and its constituents cannot be altered. Once the soil requirement of the first nutrient has been met, no more should be applied to the soil. Other fertiliser is therefore likely to be required to top up the nutrient needs of the soil. When applying the digestate to farm land, a genuine crop benefit needs to be demonstrated. If the digestate is of high P or K for example and the soil analysis suggests the additional application of the nutrient is not warranted, then it would be advisable not to apply in this area.

Nitrogen in digestate is considerably more available for plant uptake than raw slurry (refer to example in Table 19) as the long carbon compounds have been broken down in the digestion process, liberating the minerals. Land within Nitrate Vulnerable Zones (NVZ) has total organic nitrogen applications restricted, often meaning the application is less than the plants would benefit from. Greater nitrogen availability overcomes this, as the plant would absorb a larger proportion of the nitrogen.

Table 19 ~ Fertiliser Benefit of Digestate over Slurry

	Cattle Slurry	**Digestate**
Soil N-Requirement Kg/ha	**250**	**250**
N in total organic application	**170**	**170**
Nitrogen Utilisation percentage	35%	60%
Nitrogen utilisation Kg/Ha	60	102
Mineral N requirement Kg/Ha	190	148
Mineral N Saved Kg/Ha		42
N Saving £/Ha at £225/tonne 34.5%		£27.39

Source: Kurt Hjort-Gregersen Food and Resource Economics Institute Denmark.

3.10.2. Separating the Fibre and Liquor

The fibrous (solid) part of the digestate may be separated from the liquor. This could make its transport and storage more manageable. The benefits of separation can outweigh the additional cost:

- The nutrients in the liquor are more available than in the solids, meaning the nutrients placed on a growing crop can be managed more precisely
- The liquid can be more effectively placed on a growing crop to swiftly take up the nutrient and leave minimal residue also meaning cattle can graze the fields far sooner
- The dry component can be stored in a stack in a field as long as it does not leak or run, saving storage costs.

- The solid fibre is not subject to the closed period regulations enforced by the Nitrates Directive whereas the liquor is. Whilst only 10 to 15% of the volume will be taken out of the storage requirement, this could add up to a large cost saving.

Some AD operations in the US have created a use for the squeezed digestate as a bedding material for housed livestock (herds are often housed all year). This is not only cheap and clearly available all year round, but also relatively clean and hygienic.

4. REGULATORY CONSIDERATIONS

Chapter Summary

- There are regulations concerning environmental care, planning, health and incentive policies
- An accreditation for digestate is available to facilitate subsequent marketing
- Planning is a major hurdle in some cases, not so in others
- Electricity generators can become registered for ROCs and then trade them

For a biogas business using on-farm feedstocks and spreading digestate only on the same farm's land, the regulatory requirements are straightforward. It's when the feedstock starts coming from third parties that the red tape becomes more complex because it is treated as 'waste streams', and at that point it becomes critical to ensure the material within the feedstock is known and meets certain regulations.

Summary of Regulatory Considerations

The regulatory issues are multiple depending on differing aspects of the AD plant. They are as follows:

1. All 'waste-holders' have a **Duty of Care** to ensure waste is handled safely and by registered handlers.
2. The Environment Agency has introduced **Environmental Permitting** (in England). This combines the Waste Management regulations and Pollution Prevention Controls into a single scheme. In Wales or Scotland, a **Waste Management Licence** is required if an AD plant takes waste from other businesses or people and a **Pollution Prevention Control** permit is necessary for plants taking in excess of $50m^3$ waste materials per day.
3. A **Waste Carrier Licence** may be necessary if carrying other people's waste
4. If any feedstock might contain animal by-products, an **Animal By-Products Regulation** licence becomes necessary.
5. An **Assurance Standard** and **Quality Protocol** have been developed for digestate from source-segregated biodegradable waste. The digestate from assured sites will be classified as a product rather than waste material.
6. **Planning consent** might be necessary but is not in all cases
7. **Cross Compliance** requirements should still be met
8. If you are in the **Environmental Stewardship Scheme,** this should be considered,
9. **Health and Safety**
10. Registering and claiming for **ROCs, LECs, REGOs**

Figure 7 ~ Illustration of Potential AD Environmental Consideration

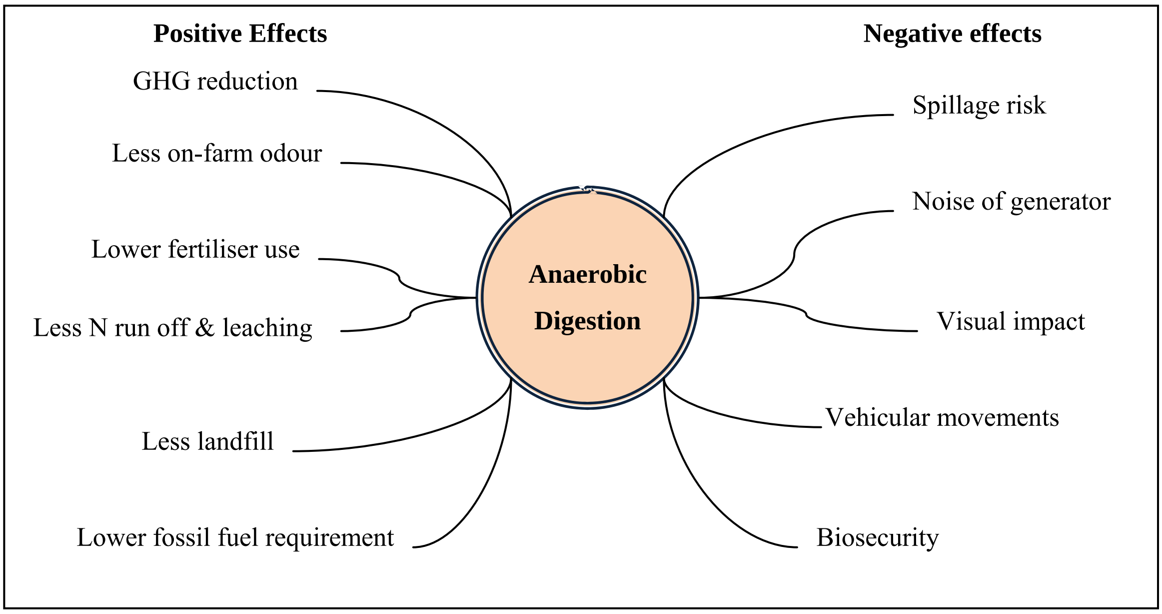


Figure 7 demonstrates that there are several environmental aspects to consider regarding AD. Much of this will be of interest to local planners rather than the Environment Agency. Note that half the points are environmentally beneficial (on the left) and on balance outweigh the overall environmental burdens (on the right). This is because:

- there are more benefits than disadvantages,
- the benefits are far greater in their environmental impact than the negatives
- the disadvantages can be minimised or reduced to 'very low risk', and the advantages increased by sensible and careful management and good planning. Environmental problems occur in all sorts of activities if they are not managed properly.

4.1. Duty of Care

Every holder of somebody's 'waste' (even their own) has a **Duty of Care** to ensure that it is removed and disposed of in a controlled and licensed manner. 'Holder' includes the point at which it first becomes waste, the carrier and the disposal point. All waste must be kept safe and before it is passed on to another body, the holder has an obligation to ensure the body is suitably authorised to handle waste. This includes farm waste streams. It involves the completion of waste transfer documentation, but no registration with the Environment Agency or other paperwork is necessary unless there is an intention to transport waste. For more information refer to www.netregs.gov.uk/netregs/63199.aspx .

4.2. Environmental Permitting (EP)

Environmental Permitting[21] is a single environmental permitting and compliance system that is designed to simplify the complex environmental administration. It brings together the two previous regulations: the Pollution Prevention and Control (PPC) permitting and Waste Management Licensing (WML) regulations

[21] *www.opsi.gov.uk/si/si2007/uksi_20073538_en_1 This is the full Regulation for the few who want to read it.*

in England and Wales (Scotland and Northern Ireland continue with PPC[22] and WML). An environmental permit (EP) is required if the business previously needed either a Pollution Prevention Control permit (covering the installations) or Waste Management licence (covering the operations). An EP (or an EP exemption) will be required if a plant handles waste at any point.

Environmental Permits are either '**Standard'** or '**Bespoke'** depending on the level of complexity. A standard permit can be used when the AD is a relatively straight forward model and fits into a 'standard' layout, with relatively low and manageable risk to environmental pollution[23]. A company with more than one facility can apply for a '**Consolidated'** permit. This brings all the facilities under one permit. Environmental Permit **Exemptions** are for simple situations of waste handling where non-waste only is being digested, this includes slurries and energy crops, or the risk of environmental damage is very low. The EP exemptions are under review, with new regulations scheduled to come in from April 2010.

Standard permits are for low to medium environmental risk sites, independent of location and used where plant can operate to a set of standard rules. They are designed for relatively common systems. The EA is developing new Standard Permit rules for AD and plans to roll them out for general use in April 2010. There will be three types of standard permit:

- For on-farm digestion, probably including farm to farm movements
- Other digesters, such as centralised AD
- Off site digestate storage.

The anticipated rates for these permits are as follows:

- Application charge £1,590
- Transfer charge £950
- Surrender charge £1,500
- Subsistence (for a plant not on farm) £2,420
- Subsistence (for a plant on farm) £1,540

Cattle slurry that is used immediately for spreading on land is not identified as a waste. However, if it is used as a feedstock for AD (i.e. processed), then it is categorised as a waste. A simple exemption is usually

22 http://www.sepa.org.uk/air/pollution_prevention__control/ppc_permit.aspx

23 www.environment-agency.gov.uk/static/documents/Research/SR2009No20_Anaerobic_digestion_facility_including_use_of_the_resultant_biogas.pdf

www.environment-agency.gov.uk/static/documents/Research/SR2009No21_On-farm_anaerobic_digestion_facility_including_use_of_the_resultant_biogas.pdf

www.environment-agency.gov.uk/static/documents/Research/SR2009No22_Storage_of_digestate_from_anaerobic_digestion_plants.pdf available allowing an AD operator in these circumstances to operate without the full standard permit[24] [25].

Bespoke permits will be required for tailored conditions where a plant is complex or unusual. These permits will be more complex to administer and therefore costly because they have to be written specifically for each plant. A bespoke permit costs between £3,000 and £8,000 to implement and also has annual renewal costs. Few AD operations should actually require a bespoke permit.

Rules of Thumb

The level of permit (or exemption) necessary is based on a series of conditions:

- An AD plant that digests no wastes (probably only energy crops) has no EP obligation
- A plant digesting slurry/FYM will require an EP or exemption, although an exemption is likely.
- A plant using food wastes as feedstocks will require either an EP or an exemption
- A site that will never have more than 1,000m^3 waste material at any time (including what is in the digester) is eligible for a licensing exemption (under paragraph 12 composting [26]) otherwise, a full permit is required.
- If energy production is not going to exceed 400kW thermal rated energy and the site does not need Local Authority authorisation, then an exemption (under paragraph 5 of the regulations[27]) can be implemented.
- If the site is to produce up to but not exceeding 3MW thermal rated energy output, then a standard permit will be required unless other environmental aspects dictate a bespoke permit.
- Above this level of thermal rated energy, then a bespoke environmental permit will be required.

Best Available Techniques

The EA is also interested to see that the facility meets what it defines as "Best Available Techniques". This includes features such as the following:

- Bunded, spill retention areas.
- Tanks and pipes not vulnerable to vehicular impact (forklift areas for example).
- An emissions management plan
- Well-planned and rehearsed fire prevention techniques, especially for methane, which is highly flammable.

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[24] *www.environment-agency.gov.uk/static/documents/Business/MWRP_RPS_045_AD_QP_V8_09-10-09_rev2.pdf (page 3)*

[25] *www.environment-agency.gov.uk/static/documents/AD_of_Agr_MS_v2_-_Final.pdf*

[26] *www.environment-agency.gov.uk/business/topics/permitting/34785.aspx, an application form and detailed guidance are available at the bottom of this page*

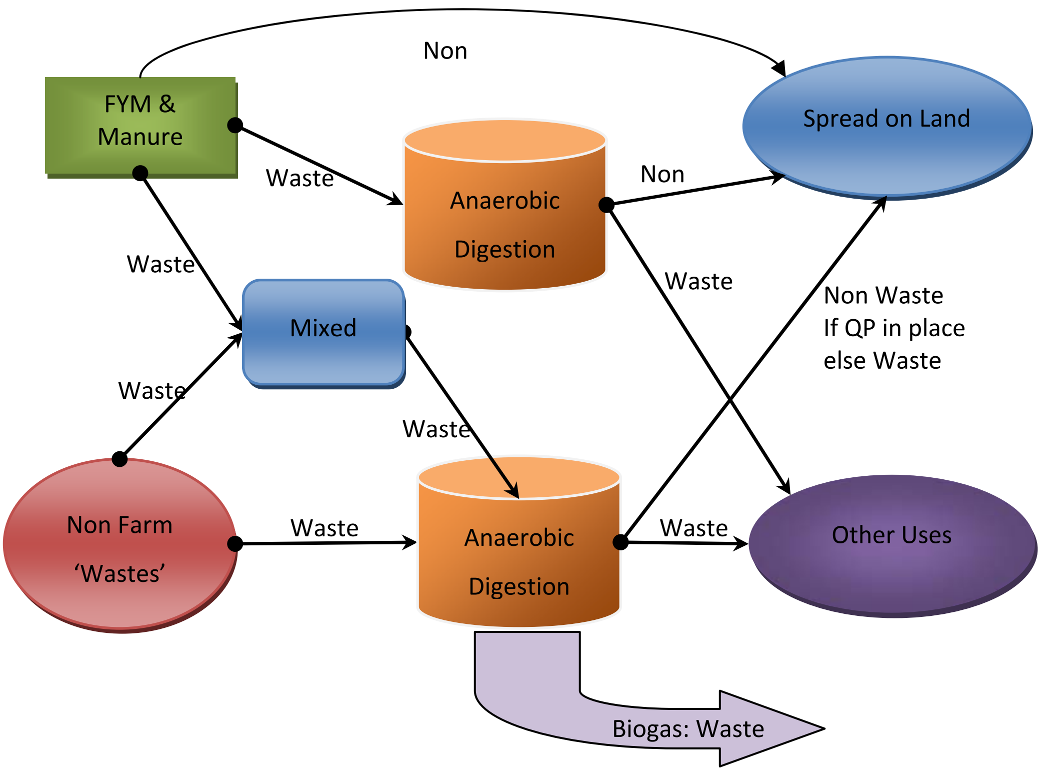
[27] *www.environment-agency.gov.uk/business/topics/permitting/34795.aspx, an application form and detailed guidance are available at the bottom of this page*

Digestate Management:

"Where the only waste feedstock to an AD plant is agricultural manure and slurry, the digestate output is not waste if it is used in the same way that undigested manure and slurry would normally be used, i.e. spread as a fertiliser on agricultural land." Environment Agency December 2008 [28]

Once an item has been classified as a waste by the EA, even when it is processed, all its by-products are recognised as wastes too unless specific declassification is awarded. Thus, whilst the digestate of AD from manure and slurry has managed to achieve a 'declassification' from waste to product, the biogas is still technically classified as a waste too. The EA envisages that once the biogas has been purified to biomethane standard, it could be declassified (through recovery), but this has not happened yet. In other words, biogas is subject to waste management regulations, particularly important if it being exported to another site for processing. An AD plant will require an EP (or an exemption) if it takes in waste feedstocks from other organisations. In these situations the spreading of digestate onto farmland requires pre-notification to the local Environment Agency office. This does not apply to a system using farm sourced feedstock streams. Biogas produced from digestion of manure and slurry is classified as a waste and so is subject to waste management controls. Figure 8 tries to clarify in a diagram what is classified as waste and non-waste.

Figure 8 ~ What the EA Defines as "Waste" and "Non-Waste"



[28] *EA Briefing Note, Anaerobic Digestion of Agricultural Manure and Slurry: www.environment-agency.gov.uk/static/documents/AD_of_Agr_MS_v2_-_Final.pdf*

Contacting the EA

This page: www.environment-agency.gov.uk/business/sectors/32318.aspx contains the links to the 6 application forms, and another link to technical documentation. The EA offices can be contacted at: www.environment-agency.gov.uk/contactus/36324.aspx or use the National Customer Contact Centre (08708 506 506) to register for a permit, or for an exemption, phone the 'agricultural waste helpline' on 0845 603 3113.

4.3. WASTE CARRIERS LICENCE

Carrying waste around the countryside cannot be done by anybody with a lorry. It needs to be carried by a registered waste carrier. The information to become registered as a broker or carrier is set out by the Environment Agency in this web-link: www.environment-agency.gov.uk/business/sectors/wastecarriers.aspx. Registration costs £149 then £102 annually thereafter.

4.4. ANIMAL BY-PRODUCT REGULATIONS

If there is any chance that animal by-products (abattoir waste or food made from animals i.e. not slurry) might enter the AD feedstock, then an Animal By-Product Regulation (ABPR) licence is necessary. This regulation augmented controls on animal by-product uses following the devastating foot and mouth outbreak in 2001. Meeting this regulation is not cheap, simple or easy. If there is any intention to follow this route, then it should be fully planned to this effect even before construction. There are three categories of material under the ABPR regulations:

- **Category 1** is the most dangerous in terms of containing hazardous diseases such as Spongiform Encephalopathy e.g. BSE. These materials are from animals known to be infected by or at high risk of being infected by these diseases. Category 1 materials cannot enter an AD plant under any circumstances and must be incinerated.
- **Category 2** (high risk material) includes the 'high risk' parts of the carcass including spinal column and brain tissues. This category therefore includes fallen stock. These materials can be digested but only after they have been rendered at 133°C at 3 bar pressure for 20 minutes and only in specifically registered plants.
- **Category 3** (low risk material) is all other animal by-product that is not fit for human consumption. This could include out of date foods (meat, dairy, eggs), leftovers and so on. This has to be pasteurised before it enters an AD plant. The heat can be sourced from the CHP generator. Reports [29] [30] suggest this can enhance methane generation and recovery by denaturing the fibrous material of the feedstock.

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[29] *Assessment of Methane Management and Recovery Options for Livestock Manures and Slurries. DEFRA 2005 Mistry and Misslebrook from IGER*

[30] *Skiadas IV et al. thermal pre-treatment of primary and secondary sludge prior to anaerobic digestion. Water Science and Technology 52, 161-166.*

There are also materials that are fit for human consumption or have no animal matter in them at all and are not categorised under ABPR such as milk and colostrum from the farm the AD plant is on may be used as a feedstock without an ABPR licence. All materials must remain identifiable at all times. If materials from different groups become contaminated, the entire batch must be treated as if it was all the higher risk category material. This adds cost and time, so segregation is important.

The system must have multiple barriers (i.e. more than one treatment stage) to reduce the possibility that any material could bypass the system and must demonstrate a 50,000-fold pathogen reduction following treatment.

To be ABPR compliant, a business must be licensed, it is a major step to achieve in several ways:

- It changes the business from being a farm with an AD plant on it to being a waste management firm located on a farm
- It involves a far greater capital investment. More machinery is required including pasteurisation technology, roadways and access routes need to be metalled or tarmac roads with two routes for access and exit. Also to justify additional expenditure, the digester size will probably be large.
- Management tasks are increased many-fold; not only does the control of feedstocks coming from third parties require careful management, they will need pre-treatments possibly including weighing, de-packaging, chopping, pasteurisation, and then blending. Ongoing monitoring of key measurements (such as temperature, and digestate quality) are all part of the HACCP principle of the regulations.
- Administration becomes complex, simply meeting the ABPR regulations (let alone the commercial side of third party waste streams) has to be robust and reliably correct.
- The risk of errors has to be driven down to as low a level as can feasibly be achieved. Nobody can ever guarantee zero mistakes, but keeping this level of performance takes considerable additional work.

It is the UK Government's objective to see AD in the UK adopted by waste management processors as well as by farm digesters. However, currently, according to DEFRA (February 2010) there are only 9 ABPR compliant AD plants in the UK. Of these, only 2 are licensed to digest Category 2 and 3 material, the rest being only licensed to process Category 3 or non ABPR materials[31]. These are illustrated on the Google map Figure 9 below.

It may not be feasible for an already operational AD business to 'upgrade' to accommodate ABP materials, as buildings and other facilities might need locating differently, for example to allow better vehicular access, space for pasteurisation units, or better segregation of waste holding tanks and digestate. Even setting up the heat source for the pasteurisation unit might need re-planning if a customer already takes the available heat. There is no cost for ABP certification other than those necessary to ensure the business conforms.

[31] www.defra.gov.uk/animalhealth/publications/ABP/section6.pdf

This site, http://www.defra.gov.uk/animalhealth/inspecting-and-licensing/abp/ provides the links for each devolved region on how to apply. The 16 page application form[32], coupled with the 38 page guidance document specifically for composting and biogas, asks searching open ended questions on how guarantees will be achieved on issues such as hygiene, cleanliness, contamination prevention and pasteurisation.

Figure 9 ~ ABPR Licensed Digesters in Great Britain

HACCP management (Hazard Analysis and Critical Control Points) is required under ABPR. HACCP is a procedure that identifies all possible hazard points, places where errors or failings can occur and removes them. It is a process developed by the food supply chain to identify any variables which, if outside a pre-determined range, might indicate (health) problems elsewhere in the chain. Critical Control Points are measurables that, if they are not within a stated range, will indicate a problem elsewhere. An example might be temperatures of feedstock or throughput rates.

Rendering and pasteurisation for Categories 2 and 3 respectively involve heat treatment for a minimum length of time:

Table 20 ~ Pasteurisation or Rendering ABP

	Category 3 **Pasteurisation**	Category 2 **Rendering**

[32] *http://www.defra.gov.uk/animalhealth/Forms/library/ABPR1.pdf*

Temperature	70°c	or 57°c	133°c
Time	for 1 hour	for 5 hours	for 20 minutes
Particle Size	Max 12 mm in 1 dimension		-
Pressure	-		3 Bars

To apply, DEFRA suggests contacting the local Animal Health Office because although you can download the forms from this website, it is the local State Vets that will handle the application and assessment. There are 24 offices in Great Britain that can be accessed at: www.defra.gov.uk/animalhealth/about-us/contact-us/animal-health-offices.htm . The application might take a while. If the State Veterinary Service is happy that the written application suggests compliance can be met, it will arrange a site visit. If not, it will write to you, explaining the shortfalls and giving you a chance to re-apply. If the inspector is satisfied at the site visit, then you will receive an approval. If not, you will receive a letter of explanation.

Achieving ABPR compliance involves additional set-up capital but the extra requirements of administration and far tighter management (including contingencies) are the main costs of processing ABPR. However, once registered, the gate fees that can be charged for taking this type of feedstock can be considerably higher. They need to be to cover these requirements. This is currently true because of the Land Fill tax, but if the rise in AD (and In-Vessel-Composting IVC) plants continues, competition for this feedstock might depress its market value. In Denmark, it is almost valueless.

As an illustration of the potential complexities, refer to the discussion on Biogen in Chapter 6.2 on page 82. The key point arising from discussion with the Biogen manager is that on paper, the application and compliance procedures appear relatively straight forward, but he considers them enormous and they totally change the structure and operation of the business, also considerably increasing the minimum critical size of the plant.

4.5. DIGESTATE ACCREDITATION

Wastes digested at a non-accredited site remain wastes after digestion. This makes the digestate difficult to market. The digestate also remains subject to waste management controls. These are:

- it must have an environmental permit or exemption to store;
- it can only be transported by registered waste carriers;
- you need an EP or permit to apply it to land[33].

More guidance on these controls can be provided from www.environment-agency.gov.uk/subjects/waste or by telephoning the National Customer Contact Centre on 08708 506 506.

To address this, a Quality Protocol (QP) has been developed to identify the point at which wastes can be reclassified as products and how compliance can be demonstrated. Where the feedstock is agricultural

[33] *under paragraph 7 or 9 of schedule 3 to the Environmental Permitting (England and Wales) Regulations 2007*

manure and slurry, either alone or mixed with non-wastes, the digestate will not be a waste if it is used on-farm as a fertiliser. This means that it will not need to be certified under the protocol.

To comply with the QP, the user has to ensure:

1. the waste is 'source segregated', i.e. it has not been mixed with other wastes not listed in the QP
2. it meets the requirements of an '**Approved Standard**'
3. its use is land based and listed in the QP

There is no obligation to comply with the Protocol. If you do not, the outputs remain waste and therefore have to comply with the waste management controls outlined above. It is important to note that whether or not the AD plant meets the criteria of the QP, an environmental permit or exemption is still required to cover the digestion of wastes and the combustion of the biogas.

QP Accreditation means digestate could be sold off farm or transferred without license. Farm Assurance schemes, buyers of agricultural products and final end consumers alike would be equally reassured that the digestate meets a minimum standard of safety. It will be administrated and audited by an independent certification body such as BSI.

The Approved Standard

There is currently only one approved standard, the Publicly Available Specification BSI PAS 110: 2008. It's draft is at: www.r-e-a.net/document-library/policy/digestate-standard-waste-protocol-development and the final versions available from March 2010 will be posted on the REA website. The Assurance Standard involves a defined agreement with the waste supplier, ensuring the AD operator knows exactly what is in the feedstock, and the operator undertakes all relevant analyses as appropriate. The principles of HACCP are used.

The Cost of Quality Approval

The costs of PAS 110 and meeting the QP are likely to be kept under review being a new scheme, and as no operators have yet passed through the scheme. initial figures from the REA are tabulated below.

Table 21 ~ PAS110 Plant Inspections and External Laboratory Testing Costs

Plant Size *(tonnes)*	Joining and Certification	Annual Renewal Fee	Residual Biogas Potential
0-6,000	£1,000	£800	£750
6-15,000	£2,000	£1,600	£750
15-25,000	£3,500	£2,800	£750
25-50,000	£5,000	£4,000	£750
50-75,000	£6,500	£5,200	£750
>75,000	£8,000	£6,400	£750 **
* RBP including Volatile Fatty Acids (VFAs) as required according to Table 1 of the PAS110 which are Pathogens, Toxic Elements, Physical Contaminants, Weeds and Crop Nutrition Value ** Frequency increases with size (from 3 to 7 tests)			

Table 22 ~ SFQC* Biofertiliser Certification Scheme Charges

Plant annual capacity *(tonnes)*	Annual Fee
Up to 15,000	£1,500
15,000 to 25,000	£2,600
25,000 to 50,000	£3,800
Over 50,000	£5,000
Group Discount 10% Annual Renewal Discount 5% * SFQC = **S**cottish **F**ood **Q**uality **C**ertification	

4.6. PLANNING TOOLKIT

AD is not considered within the agricultural planning guidelines; instead it is considered an industrial/waste treatment process. Yet if the facility is going to use only feedstock from the farm and the digestate will be spread only on the land of that farm, then it could be treated as permitted development (under part 6 of schedule 2 of the Town and Country Planning) as long as the conditions can be met[34]. Communication with local planners will still be necessary for siting purposes etc. Communicate with the regional planning office at an early stage to ensure it is on board with your intentions. Find them at:

- **England:** www.planningportal.gov.uk/england/genpub/en/
- **Wales:** www.planning-inspectorate.gov.uk/cymru/wal/appeals/advert_appeals/called_in_appeals_guide_e.htm
- **Scotland:** www.scotland.gov.uk/Topics/Planning

If the AD plant is going to require an Environmental Permit (i.e. not an exemption) then planning permission is pre-requisite. Outline planning permission is not available for waste processing sites.

Consultation with local communities, statutory and non-statutory bodies will be necessary depending on the location of the planned facility in relation to local residents and other businesses, its size and feedstock. Remember most people have a lesser understanding of AD than you so it will be prudent to explain it to local people, how it will have far less smell than the existing farm, especially at muck spreading time, how safe it actually is, how the only noise is the generator which will be housed and soundproofed and identifying any vehicular movements . Ignorance and NIMBYism (Not In My Back Yard) are probably the two major barriers facing developers with well planned plants. Siting will usually be the most important consideration to overcome these barriers. Build your plans accommodating their interests, for example;

- screening with rows of trees not only minimises the visual impact but also reduces noise impact and possibly smell.
- partially sinking the plant into the ground will decrease the visual impact of the digester. It could also facilitate site management, liquor pumping and environmental safety.
- inform local people they could benefit from cheap, renewable heat.

[34] *www3.winchester.gov.uk/SHARE1/www/planning/permitted_development/pd2.htm#6*

Planning consent may be awarded more quickly or easily to operations that specify certain feedstocks. However, the plant will not be able to adopt new feedstocks in the future without further planning consent.

There are currently two relevant **Planning Policy Statements** (PPS) PPS 7, 'Sustainable Development in Rural Areas' and PPS 22, 'Renewable Energy'. PPS1 'Delivering Sustainable Development' is of growing significance.

PPS7 states:

> *"When … determining planning applications for development in the countryside, local planning authorities should … provide for the sensitive exploitation of renewable energy sources"*
>
> *"The Government recognises the important and varied roles of agriculture, including in the maintenance and management of the countryside and most of our valued landscapes. Planning policies should recognise these roles and support development proposals that will enable farming and farmers to… diversify into new agricultural opportunities (e.g. renewable energy crops)"*

This indicates the planning system should be friendly in principle to the concept of AD.

PPS22 quotes:

> *"A planning application for an anaerobic digestion plant could usefully include the following:*

- *site plan and elevation drawings to help determine visual impact;*
- *photomontage of digester, plant building(s) and chimney stack*
- *clear indication of building material;*
- *information on grid connection works, including transformer and transmission lines;*
- *details of vehicular access and vehicular movement;*
- *landscaping provisions;*
- *site management measures during the construction phase;*
- *model of emissions dispersal; and,*
- *community consultation plans."*

PPS22 notes traffic is 'not likely to add significantly to the impact of normal farming activities'. For CAD plants, specifying lorry routes, e.g. missing villages or using main roads only or limiting delivery timings to reduce nuisance to local residents may be helpful.

The Renewable Energy Strategy[35] notes the current PPS22 is to be reviewed and a new PPS combining PPS1 (Delivering Sustainable Development) will be published in 2010. Planning Policy Statements and 'Companion Guides' can be downloaded from:

[35] www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx *page 76*

www.communities.gov.uk/planningandbuilding/planning/planningpolicyguidance/planningpolicystatements/planningpolicystatements/ .

It would also be worthwhile studying the Local Plan. These documents (there will usually be a series in each region) identify areas and types of development the local authority intends for its area. It might provide a guide to how positive or negative the planners are likely to be.

Environmental Impact Assessment

Environmental Impact Assessments (EIA) are not mandatory; there are several cases of large, ABPR compliant AD operations that have achieved planning consent without one. However, sound advice recommends that one is completed for all but the simplest of systems, because, as objections and searching questions are asked, having a EIA will show professionalism and illustrate that environmental concerns have been taken into consideration at an early stage. Being forced to produce one at a late stage of a planning application will take time and lose credibility. The cost of an EIA will clearly vary according to the nature of the application, but in most cases will be a few thousand pounds.

Business Rates

In any plant where a product is sold off farm, will be subject to business rates so most AD plants will be subject to them. The cost varies according to its rental value. Premises subject to rates are given a 'rateable value' by the Valuation Office Agency. Local Authorities use this assessment to calculate business rates. The size and type of premises are considered as well as how they are used suggesting both the physical and electrical capacity of the plant would be assessed. More on business rates is available at www.businesslink.gov.uk/bdotg/action/detail?type=RESOURCES&itemId=1073792394 .

4.7. Cross Compliance of the Single Payment

The two conditions of receiving the Single Payment (SP) are land occupation and cross compliance. Many cross compliance regulations (such as the NVZ) are legislative, others such as good agricultural and environmental condition (GAEC) regulations are necessary to receive the SP. It is not difficult to meet these regulations and have digestate but care should be taken to remain in line with the regulations. For example, GAEC 12; non-farmed land should not receive applications of inorganic manure.

Nitrates Directive

The Nitrates Directive is designed to reduce water pollution from nitrates. It is a legal requirement and a Statutory Management Requirement for cross compliance under the Single Payment Scheme. Despite many comments suggesting AD could help meet the requirements of the Directive, those within a NVZ (Nitrate Vulnerable Zone) will find this is not the case. The following points identify reasons why AD has to be carefully considered in an NVZ before investment:

- If feedstocks other than slurry and FYM are used (and this is highly likely) the volume of digestate (organic manure) will soar; digestate spreading may become a restricting factor.
- A digester cannot be used as a store throughout the closed periods because it will be full at the start and full at the end if it is used efficiently.

- Farm yard manure can be stacked in a field in an NVZ and spread during a closed period (having low available N); the digestate liquor cannot (having high available N and being a liquid). Storage requirements might therefore rocket even if the dry component of the digestate is separated.
- Storage in the closed period is necessary for the entire digestate, not just that from livestock manures (5 months unless some feedstock is pig or poultry manures, then it is 6 months).
- The whole farm maximum allocation of total N from all livestock manures per calendar year (170kg/ha) includes the fraction of digestate that came from slurry and FYM. In other words the process of digestion makes no difference to this regulation.
- The 250kg N/ha limit from any manures in a rolling 12 month period includes all digestate and includes total N, rather than just available N.
- Un-separated and separated liquor of digestate must meet the requirements of the storage requirements (22 or 26 weeks)

Refer to specific AD points on NVZ at www.environment-agency.gov.uk/business/sectors/54714.aspx, look out for question C9 and refer to www.theandersonscentre.co.uk/Free_Downloads.asp for a summary of the NVZ regulations.

4.8. Entry Level (ELS) of the Environmental Stewardship Scheme (ESS)

There are no regulations specifically mentioning anaerobic digestate in ELS handbooks. Yet as with cross compliance, care should be taken not to infringe scheme regulations. For example, buffer strip regulations prevent applications of fertiliser or manure.

4.9. Health and Safety Executive (HSE)

The Health and Safety Executive has no specific guidance or requirements for AD businesses. It notes though that every business is obliged to carry out a risk assessment of health and welfare of employees or visitors. Details of this self-auditing procedure are outlined in a leaflet called ‘Five steps to Risk Assessment’ downloadable from www.hse.gov.uk/pubns/indg163.pdf. For specific requirements, contact your local regional office, locations being listed at: www.hse.gov.uk/contact/maps/index.htm .

4.10. Accreditation for Financial Incentives

There is minimal guidance on FIT registration as yet, look out for the imminent OFGEM guidance document.

4.10.1. ROCs

Renewable electricity generating stations including biogas plants with CHP generators are accredited for the Renewables Obligation (RO) by OFGEM individually and on a case-by-case basis. Simply by having an AD plant on your farm will not be sufficient. In order to become accredited by OFGEM for the RO, you will need;

- To install an approved electricity meter

- To pass OFGEM's Test of Reasonableness

Once the generating station has been accredited, you will receive a unique, accreditation identification number. The length of time that will be required to achieve accreditation will depend on the complexity of the generation station. Accreditation will be on OFGEM's satisfaction that you have met all necessary criteria regarding renewables. Thus, providing the necessary information should speed the application procedure.

Accreditation is normally backdated to the date OFGEM receives the initial application (so keep records of posting) or the date of commission (whichever is the later) and ROCs, REGOs and LECs will be issued from that date assuming you are on a monthly recording system. Applications for OFGEM accreditation should only be made within 2 months of commissioning, although 'preliminary' applications can be made further in advance of starting electricity generation.

The minimum electricity for which ROCs will be issued is 0.5MWh as electricity generation data is rounded to the nearest MWh either monthly or annually. The default return is monthly for ROCs although generators can opt for an annual return. LECs are only issued monthly.

An OFGEM approved meter at the point of electricity generation means a small AD plant on a large business may bypass the necessity for an expensive exporting grid connection but still claim ROCs. Electricity used for the operation of the generating station must be treated as input electricity and deducted from the gross generation.

All information, application forms, guidance notes and contact details required to register and receive ROCS are available from the following web link:
www.ofgem.gov.uk/Sustainability/Environment/RenewablObl/Pages/RenewablObl.aspx

4.10.2. LECS

Climate Change Levy Exemption Certificates are introduced on page 14. OFGEM is responsible for accrediting renewable energy generators (apart from in Northern Ireland) and issuing LECS to operators of renewable power.

To achieve accreditation, a 14-page form has to be completed. It can be downloaded from the link below along with accompanying notes. OFGEM must ascertain whether the power generation meets the definition of 'renewable'. Additional information may be required or OFGEM may make a site visit. Once accredited, each station will have a unique number. Each station will be issued with LECS following provision of electrical output data from the meter reading each month end. Archives must be kept for 6 years.

Generating stations will have to undergo annual technical audits (by OFGEM) to ensure each station remains eligible and that metering has been correct. Renewable electricity generating operators have to submit an annual 'Consumption Declaration'. This certifies that the electrical output is consumed in the UK. Also on a monthly basis, OFGEM must be notified of the subsequent allocation of the renewable energy. This is provided by the end supplier (the company who sells the electricity to the end user). Remember it should be used by non-domestic consumers. It should also be noted that whilst the administration of LECs is probably small once set up, their revenue will constitute a small proportion of income, about £3,000-£5,000 for an average size AD plant.

This link holds the application form and accompanying notes.
www.ofgem.gov.uk/Sustainability/Environment/cclrenexem/Pages/CCLRenewablesExemption.aspx

4.10.3. REGOs

A REGO is simply a Renewable Energy Guarantee of Origin. It certifies that the generation of the energy was in fact renewable. REGOs are not transferable or tradable but provide authorisation of renewable credentials. These are also issued by OFGEM in Great Britain but are a pan-European label. More information and the applications paperwork is available at
www.ofgem.gov.uk/Sustainability/Environment/REGOs/Pages/REGOs.aspx

REGOs are awarded by OFGEM with every 1MWh of renewable electricity. Use REGOs to prove that the electricity is renewable. REGOs have no market value to third parties. An electricity supplier can register for REGOs on your behalf if you are contracted to supply to them.

4.10.4. Selling ROCs

You can sell your certificates either directly to electricity providers or auction them. Most licensed electricity suppliers will buy your electricity and ROCs as a single deal. Buying electricity from a renewable electricity source is commercially the same as buying it from fossil or nuclear sources without the ROC. It is the ROC which recognises the renewable credential. This will ease the administration and probably offer a fixed price for the certificates, but may not be the highest price you could generate from them.

Certificate (online) auctions take place via www.e-roc.co.uk/ . A charge of 50p per ROC is payable, subject to a minimum charge of £50. See chapter 2.4 on page 10.

4.11. Summary Cost of Compliance to Regulations

Table 23 summarises the likely costs of compliance to the various regulatory requirements. As can be seen it will vary enormously depending on complexity of the plant and its size. A small on-farm AD plant will be eligible for an EP exemption, not require the PAS 110 to meet the QP, not have ABP licensing to meet so have regulatory fees of less than £100. Whereas a complex waste management system may find costs of regulation amounting to £8,000 for an environmental permit, £8,000 to be accredited with PAS 110, say £50,000 to meet the ABP requirements and whatever else comes with the EP. It could quickly exceed £100,000.

Table 23 ~ Table of Regulatory Compliance Costs

Regulation	Cost of Regulation	Cost to conform business
Duty of Care	£0	£0
Environmental Permitting	£3,000- £8,000 ~ Bespoke £ 1,590 ~ Standard Then £1,540 to £2,420 pa	These requirements such as site bunding can be expensive, £ 0,000s ~ very costly

	£0 ~ Exemption	
PAS 110 / QP	Size dependant	size dependant
Animal Bi Product	£0	c £ 0,000's ~ very costly
Health and Safety	£0	c £500 ~ Low expense
Waste Carriers Licence	£149 initially £102 annually	

5. ECONOMICS OF AD ON FARM

Chapter Summary

- o Income might come from several areas, they should all be managed carefully.
- o The two major costs will normally be capital and feedstocks depending on operational structure.
- o Efficiency of scale is important in AD.
- o Capital grant funding or other finance may be available.

The science, physical and regulatory requirements are all understood and in place, so we turn our attention to making a profit! So many changes have occurred in the last 2 years to support, technology providers and knowledge about AD that whilst we regularly hear how viable AD can be, we need to know how that is and how to maximise it. Although AD is a relatively straightforward technology, the complexities come in running efficiently and consistently – this can be a challenge and can have a major impact on the economics. One of the biggest factors affecting the efficient operation of the plant is the correct technology, size and siting of the plant in the first place.

5.1. INCOME

Revenue from AD should come from several sources. Each output should be considered a co-product rather than by-product and marketed accordingly. These are:

- Sales of biogas (or a product from its processing such as electricity)
- Associated ROCs at present (or FITs in the future)
- Heat from biogas combustion, lowering heating bills and selling to others (possibly with RHIs in the future)
- Sales or own use of fibre and liquid fertiliser in place of mineral fertiliser

For every kWh of electricity that is produced, income is currently likely to be:

- Sale of electricity to local electricity supplier, wholesale value of about 5p/kWh
- ROC value, 0.002 ROCs per kWh, worth about 10p/kWh (or 9 or 11.5p from Generation Tariff)
- Heat value. Some will be returned to the plant but say 80% sold at 1.5p/kWh
- LEC, usually as part of the electricity sale price
- Fertiliser value. The benefit here is small but important and depends on the feedstock.
- Total revenue at today's values per kWh should be about 16p or £160/MWh. Clearly this will vary according to negotiated deals.

Achieving Capacity: Theoretically, the total production of heat and electricity over a year is the capacity multiplied by 8,760 (the total hours in a year). The vagaries of AD production and the electricity contract will mean this will not be achieved. The REA suggests 85% capacity is a fair multiplier and AD technology supply companies suggestions range from 80% to 99%. Although comparing organisations' published capacities with their ROC registrations (Table 8 on page 20), 60-70% seems more realistic. It also illustrates that the unpredictability of third party wastes makes operating an AD plant at full capacity very difficult. This is clearly a critical point to maximise whichever system is being operated. Careful observations of the critical control points coupled with a reliable relationship with feedstock suppliers could make the difference between paying off the capital within 5 years or 15 years.

Offset Costs: There could be changes to farm practice that don't directly provide an income but offset costs. Digestate liquor for example is easier to pump than slurry (depending on its dry matter percentage), and being more readily available, the absorption of nutrients into the crops it is placed on raises its value compared with raw slurry. It is for reasons like this that whole farm costings are better than partial budgets to identify the full benefit of an AD operation within the farm system.

A Scottish Executive, Water Division report[36] found that AD treatments can lead to a "significant reduction in the amount of nitrate leached following land spread," as improved infiltration rates reduce run-off and improve the efficiency of the plant's nutrient use. This presents the opportunity to make savings regarding artificial fertiliser. The worksheet in the associated spreadsheet exploring the value of the digestate finds a cubic meter of digestate worth over £2.30 at today's values but varies according to dry matter and feedstock. Farmers' fertiliser costs will not necessarily be totally removed, but certainly reduced.

5.2. COSTS

The two major costs in anaerobic digestion are the initial capital set-up (and associated finance) and the cost of feedstock, depending on the system selected and feedstock used. More slurry and farm waste will mean more 'free' biogas, but having a very low gas yield per wet tonne of feedstock, a larger digester will be required to accommodate a greater tonnage of throughput. Once the plant is set up, it should have relatively low operating and maintenance costs other than the feedstock.

Feedstocks: As with any budgeting exercise, all enterprises should be treated as individual cost/profit centres. Table 24 gives examples of purchase or transfer values into an AD plant budget at February 2010 prices. These are, in effect, 'opportunity cost' values i.e. what the product could be sold for on the open market or transferred into another farm enterprise (such as dairy). There is therefore an element of profit attributed to the crop enterprise. If a business charges the feedstocks at their 'cost of production', their values may be different.

Table 24 ~ Example Feedstock Prices

Feedstock (£/tonne)	**Cost**
Maize Silage	£25
Grass Silage	£22
Wheat (grain)	£90*
Barley (grain)	£80*

[36] *by Greenfinch Ltd and Enviros Consulting Ltd* www.scotland.gov.uk/Resource/Doc/1057/0048383.pdf

Pig Slurry	£0.00
Cattle Slurry	£0.00
	Revenue **
Green Waste	c£20
Food Waste	£45 +

**Costs are based upon current prices on the open market February 2010*

*** These are based on various contributions but will vary considerably according to local outlets.*

The production of crops for AD changes the whole-farming system. For example, the reduction in the area of other crops may have rotational implications when replaced by maize. Such changes also impact upon machinery and contractor use, thus affecting investment/replacement policy. The important point is to divide the crop production enterprise from the AD enterprise, putting them both into separate cost centres. An internal transfer can then be made from one enterprise to the other.

Transport: should the supply of feedstock and the removal of digestate necessitate vehicular movements the costs will very rapidly escalate. One recent study estimated a net cost of the digestate from a particular AD plant to be £12 per tonne; this is after the value is taken into account. Whilst digestate is a valuable soil conditioner and fertiliser, its low dry matter content makes it very expensive to move. Careful calculations on what land will be required, where it is and how the digestate will be delivered must be made. When costing imported feedstocks, it is sensible if possible to consider their values/costs on a delivered to site basis.

Utilities: external costs for electricity and gas should be zero or near to zero if the system is set up correctly to use the electricity generated. The electricity required will be taken from the generator, although the requirement to power the feedstock pump and light the engine room is likely to be comparatively small. As a useful rule, a range of 4-8p/kWh electricity is used per tonne of feedstock. This will vary depending on:

- How efficient the system is,
- What kind of agitation is used and therefore how much power is required for it
- Whether it is a dry or wet fermentation (contributing to the above point)
- What pre treatments are necessary such as chopping, pasteurisation, de-packaging and so on.

A certain amount of heat will also be required to heat the digester, usually in the range of 5-60 percent. This can be taken from the heat generated by the CHP (when this is what the biogas is used for). A high dry matter plant with a long retention time will not require as much heat as there will be less water to warm up and as the feedstock remains in the digester for longer, keeps its warmth. Conversely a digester with a very brief retention time will take more heating. Clearly, the thermophilic plants will use more than the mesophilic systems.

Some water to clean the surrounding area might in some situations be required. Water to feed into the digester need not be tap water. If regular applications of water are required to ensure the right liquidity, this could be from collected rainwater.

Insurance: Insurance costs between farms vary considerably. Indeed, some existing farm policies cover certain small-scale on-farm AD operations. Some AD provision and support companies such as Schmack-Biogas provide machinery and hardware breakdown insurance cover themselves. Once running, AD is a relatively safe and reliable procedure as long as safety procedures are adhered to. A budgeting figure of 1% of capital is sensible for budgeting purposes until the insurance quote is provided.

Maintenance and Repairs: The cost of maintaining a well built anaerobic digester tends to be relatively low in comparison to its capital value. Indeed, the budgeted costs of maintaining the plant is often based at about 2 percent of its capital value. However, we bear in mind that having a high capital cost, its maintenance can rise to several thousands each year. It is better to keep the plant well maintained, than to allow it to run down, then require major works which could take months to empty, refill, reheat and re-establish the micro-flora.

The maintenance of the CHP generator is slightly different. It is usually calculated as a cost per kW electrical generation. An efficient plant aught to cost no more than 0.75-1p/kWh e, others can cost as much as 1.4p/kWh e. most generator providers also recommend a major rebuild after 15-20,000 hours (2-3 years) of operation. This might either be built into the support package provided or at separate cost. Watch out for contractual details here. The CHP generator will not be expected to last as long as the AD digester; corrosive biogas and fairly constant use takes its toll after 8-12 years. Again, it is worth making adjustments to forward budgets to prepare for this replacement cost.

If and when something does go wrong in a digester, it can be very costly. For example, if a part of the agitation mechanism within the digester snaps, then to replace it would entail stopping the digestion process, emptying it and replacing the broken part, not to mention the time required to refill and heat the digester again! This is why it is clearly worthwhile making sure that set-up expenditure is not scrimped on.

Labour: The labour requirement of an AD operation is not proportional to the electrical output or capacity, but the complexity of the system adopted. A system taking large volumes of slurry and only small amounts of other feedstocks will require only an hour or two per day (refer to The Centralised Danish System Case Study in chapter 6.3). Alternatively, a complex business structure taking third party waste streams and blending them will require more. The Case Study on Biogen in Chapter 6.2 illustrates a model that uses 3-4 staff. Labour requirement will depend on a number of factors, including:

- What pre-treatments are required and whether this is automated
- The end use of the gas
- How the fibre is marketed (although this could be classified as a separate enterprise)
- Type and volume of feedstock
- Level of automation

Those systems using energy crops as feedstocks must, of course, note the time required to grow, harvest and ensile the crop whilst ensuring it is not double counted. Each AD operator has commented on the importance of a committed staff, with a genuine interest in making the system work.

5.3. Capital Investment

Any AD operation will involve a high capital set-up. The feasibility study and project development costs are easily forgotten. These include planning, professional fees, expert advice, time and effort and training. The longer the capital investment can remain operational, the greater the potential profitability of the project will be.

Rule of Thumb Figures: The capital set-up of an AD plant is likely to cost in the region of £2,500 to £6,000 for every kW of electricity generating capacity, averaging at about £4,000/kW. This is clearly a considerable range. A small plant requires the same facilities as a large one albeit in a different scale. Larger plants can benefit from greater economies of scale making the likely return on capital more positive. The Good Practice Guide[37] states a small plant of 10KWe capacity using residues from 100 cows or 1,000 pigs would be a digester of 150m^3 costing £60,000 to £70,000 (although few would be able to make a plant this small financially viable). A complex 1MWe plant (with a 10,000m^3 digester) will cost £3m to £4m.

The capital cost of an AD plant per cubic meter of digesting capacity tends to sit in the range of £400 to £750 per cubic meter, averaging somewhere slightly over £500/m^3. Just as in the previous rule of thumb, different systems and feedstocks will vary their costs enormously.

Additional Capital: Beyond the headline figures supplied from the biogas company you decide to work with, remember the additional costs they will not be responsible for. These might include the cost of electrical connection or building an additional nearby silage clamp, roadway preparation and earth works. They should be clearly costed as these can add up to substantial amounts. See the example spreadsheet and check list at the end of this document.

Much of the detail as to which cost/profit centre incurs the cost of storage/disposal depends on the AD system itself. For example, a dairy farm that already has a slurry lagoon and subsequently invests in an AD facility will attribute the dirty water storage post AD to the dairy enterprise (as previous slurry storage will be replaced by storage after treatment). However, should that AD plant incorporate energy crops or third party wastes, the storage of the additional digestate may well require a second lagoon, the cost of which will be incurred by the AD business.

Storage: The John Nix Farm Management Pocketbook[38] figure for capital cost of slurry storage is £200 - £250/cow for 120 days. This will be equivalent to circa 2,500 litres slurry. Thus 10p/litre storage capacity should be used for budgeting purposes.

Capital Accounting: It is notable how many AD plant proposals do not correctly account for the capital expenditure. Ensuring the capital expenditure in management accounts is depreciated correctly is important in AD businesses because, as already discussed, the capital cost of AD is the major cost. The capital needs to be allocated across the years of the plant's expected operation gradually by way of depreciation (usually straight line). This will prevent the total capital cost appearing on the profit and loss in a single year and returning a massive loss in year one and also correctly adjust the value of the balance sheet. Cash-flow and

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[37] *Good Practice Guidelines ~ Anaerobic Digestion of farm and food processing residues*

[38] www.thepocketbook.co.uk

profit are two separate account documents and should be treated as such. Speak with your management advisor for more on this.

5.4. CAPITAL GRANT AID AND OTHER OPPORTUNITIES

There are capital support schemes available to assist with biogas plant construction. It was not clear for some time how these schemes fitted with the payment of the second ROC and it appears the same might be the case with FITs, although the response to the consultation has diluted this considerably refer to page 17 for details.

5.4.1. Rural Development Programme and LEADER

The Rural Development Programme (RDP) comprises about 5% of the GB CAP allocations (with €1 billion between 2008 and 2013). It is part of the second pillar of the CAP and is designed as a capital pump priming grant for initiatives that diversify or increase the competitiveness of land based businesses. AD fits neatly into these 2 categories.

The grant money is administered by the Regional Development Agencies (RDAs) in England[39], the Welsh Assembly Government in Wales[40] via the Farming Connect programme, Dardni in Northern Ireland[41] and the Scottish Government administers funds[42] mostly through its Rural Priorities, the third tier of its Rural Development Contracts programme.

Applications can be made by individuals or groups. Up to 40% grant aid is available for on-farm AD plants if less than 50% of the outputs are exported. This might rise to 50% grant availability in severely disadvantaged areas. In many regions, grant assistance is also available for feasibility work ahead of capital investment as long as the consultant is registered and approved. Speak with your regional organisation or consultant for local information. Anaerobic Digestion is looked upon favourably by most RDAs, and indeed has even been mentioned in their literature.

LEADER is a locally administered part of the RDP only available in some areas. Whilst funds are smaller than the main RDP, LEADER funds might be useful for adding value to the study, for example for providing training, or marketing assistance or other specific elements.

5.4.2. State Aid Funding

EU State Aid regulations dictate that single businesses cannot receive above a certain level of state funding over a three year period. Farmers claiming capital grant on an AD plant processing on-farm waste through RDP can claim up to 50% capital and also claim 2 ROCs per MWh. Entrepreneurs building an AD plant to digest third party waste streams too can also claim RDP but only up to a 20% limit or €500,000, whichever is greater. This €500,000 will fall to €200,000 in December 2010. Double ROCs will also be available.

39 www.englandsrdas.com/contact/

40 wales.gov.uk/topics/environmentcountryside/farmingconnect/?lang=en

41 www.dardni.gov.uk/index/grants-and-funding.htm

42 www.scotland.gov.uk/Topics/farmingrural/SRDP

5.4.3. Enhanced Capital Allowance

An Enhanced Capital Allowance (ECA) scheme is available to offset 100% of capital expenditure on energy saving capital investments against taxable profits in the year the investment is made. This is available for CHP plants (but not the capital involved in the biogas plant). Businesses can write off the whole of the capital cost of their investment against the taxable profits. The general rate of capital allowances for spending on plant and machinery is 25% a year on the reducing balance basis. ECA claims should be submitted as part of normal corporate or income tax returns.

Minimum standards need to be met by the CHP generator, achieving a CHP Quality Assurance certificate (CHPQA) and Certificate of Energy Efficiency. These enable businesses to claim ECA. The CHPQA is discussed on page 41 in Section 3.8. For more information on ECA speak with your accountant.

5.4.4. Bio-energy Capital Grants Scheme

This scheme is designed to support the installation of biomass fuelled CHP projects in England. It opens and closes in 'rounds'. The scheme provides funding of up to 40% to a maximum of £100,000 of the difference in capital cost of installing a biomass CHP and a fossil fuel alternative. Eligibility extends to biogas for CHP. Future rounds of application are scheduled through to 2010. Guidance notes and application forms are available from www.defra.gov.uk/foodfarm/growing/crops/industrial/energy/capital-grants.htm.

The **Bioenergy Infrastructure Scheme** is eligible for the development of the supply chain required to harvest, process, store and supply biomass to heat, combined heat and power, and electricity end-users. It is not really eligible for AD but those looking to use switch grass or other dedicated energy crops might be eligible. Refer to www.decc.gov.uk/en/content/cms/news/pn136/pn136.aspx for details.

5.4.5. Other Grant Aid and Support

The government is providing £10 million for a new AD **demonstration programme**. Four large-scale facilities will show the potential of this technology to create renewable energy, reduce greenhouse gas emissions and avoid waste being sent to landfill. It is being implemented through a fund called the **Environmental Transformation Fund**. Find it at:
www.wrap.org.uk/recycling_industry/information_by_material/organics/etf.html.

The **Carbon Trust** has £5 million to encourage the development of second-generation biofuel technologies. This includes the use of biogas for road fuel. www.carbontrust.co.uk

The **Waste & Resources Action Programme** (WRAP) has an Organics Capital Grant Programme which is currently open. It provides financial assistance of up to 30% towards the capital costs of plant, equipment and infrastructure for food waste processing capacity compliant with the Animal By-Products Regulations in England, Northern Ireland and Scotland.
www.wrap.org.uk/wrap_corporate/funding/capital_grants/index.html

A summary of the grants available is at: *www.defra.gov.uk/environment/waste/ad/market.htm*. There may also be other **local support** for setting up an AD plant.

5.5. PRIVATE EQUITY FINANCE

Setting up a biogas plant of whatever scale will incur significant capital investment. The return on a well designed plant should be reasonable so banks and other financiers will probably be interested as long as the management is good and balance sheet adequate to accommodate a percentage of the project costs.

A bank as a source of funds would charge a minimum return (the interest rate) but then take no further margin. Venture Capital funding is normally more flexible expecting low returns in years of low business surplus, but would take a proportion of the profit in more successful years. There are several sources of finance keen to share equity of well-run UK AD operations.

As new technology becomes more proven as a likely income generator, companies who make their business from investing in other people's projects become more relaxed and take on greater risks or settle for lower returns. When AD was first commercialised, these funds sought an annual return on capital of about 20%. Now, this has apparently fallen to as little as 7%. Furthermore, many investment funds have been set up that focus on renewable or sustainable companies. In order to attract such capital support;

- a project manager needs to be able to illustrate a detailed cash flow projection as the primary evidence of business success.
- Investors will be interested in margins on turnover. This is important as an assessment of risk. If the main trading expense goes up in price (feedstock), or the main output fell in value (electricity, ROC or gate fee), to what extent would the business remain viable? FITs largely remove this risk.
- Management ability would be scrutinised for competence and experience.
- Investment companies prefer the companies they invest in to employ professionals for fundamental procedures, cautioning DIY.
- Security of assets must be negotiated, if all fails, who takes the assets. If you tie everything in your favour, the return they demand is far higher.
- Transferability of assets. Whilst the concrete digester tank might not have a high transfer value, the CHP, additional tractor and pumps etc might do.
- Supply contracts for inputs and outputs must be negotiated in advance and agreed for term of payback.

Funding from the city can be available at the point of construction. The more preparation undertaken, the lower its cost will be because risks are removed. If you are not familiar with a particular type of capital funding stream, make sure you fully understand it before signing anything.

5.6. ECONOMIES OF SCALE

How should a farmer decide what size AD plant to build? If it is to simply digest the slurry from the livestock enterprises, then that should be straightforward to assess and calculate future plans. However, this could straightjacket the farm system to changes in future strategy. The Case Studies include one of the smallest and possibly the largest on-farm AD operations in the UK so far. One takes an hour a day to manage, the other has a team involved. One generates more electricity per hour than the other does in two days. One shuts down for summer, the other stays at full capacity. It is like comparing a major supermarket with a local farm shop; both successful in their own ways. In most business situations, the larger the business becomes, the more economical it is as long as:

- It operates at full capacity
- The management remains as tight as it would be if it was small.
- Additional costs such as greater haulage distances do not negate any additional gain.
- The additional capital required can be managed without damaging the wider business.

The business will need to assess more than economies of scale. The greater a development, the greater the **risk** involved. More factors become fundamental to the success of large operations than small ones.

Any of several factors could become limiting factors determining the maximum AD size. These include:

- The availability of feedstock either from an ‘on-farm’ source or elsewhere.
- The area available to spread the digestate (especially the dirty water), especially for those businesses within the NVZ areas of the UK. Refer to the associated calculator to work out your limits.
- The amount of capital available to create the project, including gearing and financial support from lenders and grants.
- The ability and spare capacity of the management. Whilst more can be brought in (clearly at additional cost) new and large operations will inevitably place a work and responsibility burden on the overall business manager.
- The impact the operation has on the rest of the business. Any AD enterprise will probably be of sufficient size to change the farm structure, but should it support the farm business, become fundamental to it or completely dominate it so the other enterprises become little more than a distraction? The latter is when it has become a waste management operation.
- The rising costs of haulage (of relatively low valued items) the further they have to be sourced.
- The physical size of the facility, especially if it is within sight of other premises.
- The risk of losing third party business.

Collaborations between businesses lend themselves logically to larger scale operations making best use of a greater pool of skills and resources. It can be difficult for two livestock farms to collaborate because of biosecurity issues, notwithstanding the proven CAD system, it might prove more robust for a livestock business to cooperate with an arable farm.

5.7. Other Business Issues

5.7.1. Business Structure and how AD will fit in.

There are several other issues that need to be clearly explored before entering into an agreement with an AD technology constructor. It is not complicated to assess the profitability of a biogas enterprise, decide which use of the gas is most likely to meet your objectives and build a plant. What is more complex and requires time and an open mind is how the plant is likely to affect your existing business. There is a whole gradient of scenarios from ideal to not-suitable. The two extremes are probably as follows:

1. The plant employs spare capital the business has been holding, provides tasks for staff with spare capacity, uses a waste product from the farm or nearby and provides fertiliser and heats farm enterprises. The renewable energy adds value to an existing food brand from your farm shop.
2. The plant requires additional hectares of energy crop meaning the existing arable rotation is reduced, making it less profitable. The staff and management are already hard pushed to complete their existing workload and more staff will overload the management meaning yields fall in other areas of business. The plant is located near to some let stabling or holiday cottages which, whilst offering renewable energy, might not offer the ambiance that holidaymakers or riders prefer.

The second case is unlikely and issues like this are surmountable (sometimes at a cost), but taking a consideration of how the plant is planned to fit into the existing business structure is a highly important exercise. This is an area many renewable energy studies overlook.

6. CASE STUDIES

Chapter Summary

- Six case studies explore extreme contrasts in UK and EU AD
- Walford and North Shropshire College proves that small and simple can work
- Biogen makes most revenue from non-farm feedstock, through gate fees and raised gas yields
- CAD systems in Denmark are established and proven systems of cooperation
- The Danish pig farmer does need non-farm feedstock to augment biogas yields
- The German based study shows how mostly home grown energy-crops is profitable but may have a small return on capital
- The last study explores issues of planning an AD plant

6.1. WALFORD & NORTH SHROPSHIRE COLLEGE ~ SHROPSHIRE UK (2008)

6.1.1. Background

The Walford campus of Walford and North Shropshire College is a few miles west of Shrewsbury. It has a mixed farm comprising a 220 cow dairy unit and relevant followers, a 60-hectare arable unit of wheat and spring barley and a sheep flock. The dairy land covers about 100 hectares, 70 of grass and 30 of maize. The sheep account for another 20 hectares of grassland. The straw is baled for the livestock. The college farm had an AD plant installed in 1993 as an experimental unit to explore its viability in a farming scenario. It is probably the oldest fully operational on-farm AD unit in the UK. It is therefore an ideal AD operation to examine as a case study in this report.

As the farm is part of a land-based college campus, the farm manager has multiple objectives to meet. Just like any other farm or business, the plant has to be financially viable, but must also focus the operation on training and learning for the students at the college. Any major capital investment has to be justified not only in terms of farm profitability and viability, but compete with the opportunity cost of investing it elsewhere throughout the campus.

When the AD plant was built, the farm had a 130 cow-dairy with followers and a 180-sow pig enterprise. Both provided suitable feedstock for digestion; the cows, throughout the winter months (whilst they were housed) and the pig manure, although yielding slightly less biogas, was continuous throughout the year. Now, with only cow slurry feeding the digester, whilst the cows are out in the summer months, the slurry is not collected and the digester is idled.

The farm wound up the pig enterprise in 2000. This clearly had implications on the AD operation. However, as part of the farm business reorganisation, the number of cattle increased by nearly 100 to its present number. This business restructure worked out well for the supply of feedstock into the AD operation (at least in the winter months), but it highlights the importance of considering the AD in the light of possible future business structure changes. Whilst all enterprises should be considered before changing a business structure, one enterprise should not support another loss-making enterprise. Indeed, for a short while, the farm took in chicken manure from a nearby poultry farm to fill the gap. This was at no cost but for overall economic reasons, was discontinued.

6.1.2. The AD System

The AD system in place was built by Farmgas (a company that has since been bought). It is a wet, single tank, mesophilic digester, with a 330m^3 capacity providing a very small working capacity of 300m^3. These cows produce about 60l slurry every day.

- 60 litres X 220 cows = 13,200 litres slurry per day = 13.2m^3 per day
- On the basis that the slurry/feedstock remains in the digester for on average 20 days, this leaves a tank capacity of 264m^3 plus any production from the followers.

The slurry is pumped into the digester daily after scraping out. The slurry passes through a chopper to ensure any straw that might have reached that point doesn't block the pipes.

The digestate removed is separated into a dry fibre (which is stored in a shed), and the liquor, which is stored in a 1,000 cubic metre (1 million-litre) uncovered lagoon. Every year, the process makes 3½ million litres of liquor so is emptied 3½ times. This can be emptied onto the farmland in 8 hours by pipes and pumps. The land area on which this can be spread is seen as a limiting factor to increasing the use of the AD plant. This is partly as the time involved and cost associated with tankering the liquor beyond the farm is excessive. Secondly the amount of liquor a field can receive is restricted by the NVZ regulations (refer to the paragraph on the Nitrates Directive on page 63).

The biogas generated is piped through a scrubber with iron filings and swarf from the metal-work rooms. This is one method of decreasing its level of hydrogen sulphide. Twice a year, the filings are washed with water, a process that 'resets' the filings. It is not 100% effective but cheap. No gas is stored beyond that collected at the top of the digester. The rise in gas pressure at the top of the digester automatically triggers a motor that starts a CHP generator. Once running, the motor closes down leaving the generator running. This tends to run for about 20 hours in a day. The farm records show that about 75,000 kWh of electricity are generated each year (75MWh e). If it was to run for 12 months on slurry, this could be increased to about 110 MWh e, and if higher yielding feedstocks were incorporated, this would clearly increase further (potentially dramatically).

6.1.3. The Economics

The plant cost £135,000 and was 50% grant funded being for educational purposes. Being 15 years old, the capital has been depreciated to a low level. The electricity generated is used on the farm and at the college. The amount of electricity generation has been metered in recent years and offset's their requirements from the National Grid. There will be occasions (such as college holidays) when the electricity production from the AD plant exceeds the total farm and college requirement.

As the power supply to Walford campus and farm have been on a single meter, it has not been clear how much has been generated and therefore netted off the requirements from the grid by the main part of the college. The power supply is also connected up to the college, and whilst the college does take an electricity supply from the National Grid, this is a one-way meter and any surplus has not been sold.

The farm manager has observed a greater grass growth response to applying waste water from AD than applying slurry. It helps make excellent silage. As discussed (Section 3.10 on page 48), the nutrients are more available in AD digestate than slurry. The added value of the nutrients and greater ease of spreading is estimated at being worth about £2,000 per year.

Annual repairs amount to about £3,600. No additional insurance is required because of the AD operation as there is no gas storage and none under pressure. The farm operates a strict no-smoking policy. Labour requirements have been estimated at about one hour per day, albeit in blocks when maintenance is required.

The dry fibre is sold separately at £12/tonne ex-farm. The farmer charges for delivery (man plus tractor and trailer) as a separate enterprise. This is a low value commodity sale. The farm manager identifies potential to add value by branding, bagging or properly marketing the fibre, but also understands this would require considerable labour and management time, possibly consuming any additional financial benefit. He also recognises the objectives he has for the farm are more agricultural than retail.

Table 25 ~ Present Economics of Walford Farm AD Project

Income	**£**
Offset electricity 77,000kWh @ c15p	11,550
Hot water usage	2,700
Fertiliser and offset spreading costs	2,500
Fibre sales (300 tonnes @ £12)	3,600
Total Income	**20,350**
Costs	
Capital amortised £135,000 @ 7% for 15 years*	7,425
Feedstock	0
Other costs and overheads and labour **	6,000
Total Costs	13,425
Profit	**6,925**
* This includes the 50% capital grant halving the amortisation cost. ** £3,600 repairs & maintenance, 2,400 labour, electricity net from income	

6.1.4. Business Options

The college farm has several options to go forward to develop the AD business if it wanted to. It also has other considerations with regards its parent business, the capital available to inject, logistical and manpower issues too.

The farm is considering making more use of the AD plant as a resource, and as an educational facility. It would like to keep it running all year, raising its revenue potential and remaining open to public and students to learn about AD. This would require introducing an additional feedstock for the summer months. Two ideas have been considered. Either:

- cropping 6 hectares (15 acres) of maize, to produce about 250 tonnes of maize silage, or

- trying to attract a supply of 'third party' green waste.

Although the farm already has silage-making machinery, considerable additional costs would be required including a storage pad/clamp for the silage. Additionally, the AD feedstock input mechanism would require adaptation, and the manager is concerned about the additional manpower required to feed the plant daily. The opportunity cost of the land (whether additional land is taken on or some taken out of the present rotation) is very high. As the arable unit is capable of handling far more land without stretching any resource, any additional land could be easily cropped with minimal additional fixed cost. The manager is also uncomfortable with the concept of producing a crop to feed the digester, not through a stand in the 'food or fuel' debate, but simply because with so much potential 'green waste' available locally, it seems sensible to use it.

It appears a supply of green waste would be mostly available in the summer months whilst the slurry was less so. It could also generate a 'gate fee' and keep the cropping rotation unchanged. On the surface, this appears sensible but would introduce certain risks and some expenditure too, depending on the level of commitment:

- Any deliveries (that involve a financial transaction) would involve an administrative burden. At a very low-level, simply counting the trailer loads and charging appropriately would be the minimum.
- If more companies became involved, a contractual commitment that only green (plant) waste was contained would become necessary, or beyond a certain point of scale, a separator might become inevitable. This could include a magnetic separator, and plastic removal. However, as wood is not digested in the digester, the precise specification of what can and cannot be tipped on site would be important.
- Commitments to deliver only green waste will avoid high cost requirements to comply with Animal Bi-Product regulations but the farm would require an EP.

In this situation, the farm manager feels he would be able to achieve gate fees of about £15-25/tonne; on the surface it sounds relatively lucrative for minimal investment. However, more time would be involved, processing the feedstock and feeding the digester, and alterations to the feed intake system would be required. Whilst neither cost is likely to be prohibitive, they have not yet been fully calculated.

The farm is also aware that across the farm track from the AD plant is the college's equestrian centre. Clearly, students and visitors to the horses would not be pleased to arrive with several tippings of any kind of waste. This is an important consideration for the college. If the college does increase its AD operation, it will have to decide what to do with the additional gas. Some plans are afoot to develop spare buildings and use the existing CHP plant to provide their heat and electricity and possibly also for the equine centre. This assumes that supply and demand will remain in balance.

The college now claimed any ROCs, having not measured the electricity generation. If the surplus electricity generation is likely to be significant, then a two-way electricity meter may become viable, but the college is aware that the surplus is presently minimal and would never repay the costs of upgrading their grid connection at the present rate of generation. However, if the college can identify how much renewable energy is being generated and used on site, it would still be able to claim ROCs and LECs even without selling any electricity. All electricity generated is eligible for ROCs apart from that which is used to generate more electricity in the biogas plant.

6.1.5. Lessons from Walford & North Shropshire College

Even small AD plants that are kept operational for several years, with a regular ‘market’ for the electricity and very low labour requirements can in fact offer a return albeit a small one. This plant, having the advantage of a 50% capital set up grant becomes viable. If this was operated on a fully commercial format, more revenue could be relatively easily generated from it, and indeed, ROCs claimed.

Walford & North Shropshire College has managed to prove that a very small AD operation using only livestock slurry can provide a profit and return on capital as long as it is kept operational for several years. Inflation since the plant was first built has eroded the capital cost considerably but not affected its functionality (short of the maintenance requirement). In 15 years time, those investing now (in good quality biogas technology) might look back and think the same. Furthermore, Walford & North Shropshire College has managed to demonstrate that biogas can work even when the biogas plant is closed for 5 months of the year and fed solely on low yielding cow slurry.

6.2. BIOGEN (2008)

6.2.1. Background to BIOGEN

Located a short distance to the north of Bedford, Bedfordia Farms (part of the Bedfordia Group) claims to be one of the top 25 farm businesses in the UK. It covers 2,200 hectares of arable land and has 1,100 breeding sows from which it annually supplies 23,000 finished pigs direct to major supermarkets.

Whilst still being very strongly rooted in primary agriculture, the Bedfordia Group has also diversified into other business sectors including car sales, property, grain storage and trading and what it describes as ‘eco-technology’. Within their eco-technology category is BIOGEN, an on-farm AD operation.

Since this case study was first written, the BIOGEN group has merged with another company and is now called BIOGEN-Greenfinch. This does not alter the lessons learned from this case study. The businesses published developments have been updated in this study.

The plant was designed in 2003 to solve the problem of the considerable amount of pig slurry the farm was having to deal with as well as seeking new opportunities for the business. BIOGEN digests the slurry from its newest finishing plant, mixed with other people’s food waste. The plant can digest 42,000 tonnes of feedstock per year, about 12,000t of which is from the adjacent 4,800 pig/year finishing unit and 30,000 tonnes is food waste. BIOGEN has about a dozen businesses and authorities within a 30-mile radius supplying their food waste both via a single waste management company and directly.

6.2.2. The BIOGEN Operation

The pig slurry is pumped into the AD plant via an underground pipeline. The food waste, on arrival goes through a packaging removal unit, then is pasteurised by pulverisation and heating to meet regulatory requirements (see page 56). The heat is from the CHP unit.

There are two vertical tank digesters of 2,200m^3 each. They are automatically fed every 4 hours from two storage tanks. This allows the feedstock 'mix' to change gradually. This is one of the greatest technical challenges of an AD operation of this sort. This 'little and often' feeding system has smaller impacts on the temperature, pH and bacterial mix within the digester. It operates at a mesophilic 40^{o}c, using a third of the heat created from the CHP. The feedstock remains within the digester on average for approximately 30 days.

This AD operation annually produces 30,000 tonnes of wet digestate that is spread as a fertiliser over the associated arable farm. This is piped to the fields without separating the solid fraction, which remains in suspension. Having a large arable farm within the group, and on a single location means the land area is not a limiting criterion, despite being within an NVZ. It also appears that levels of trace elements and heavy metals are not causing or likely to cause an issue on the land.

The gas is fed into 2 CHP generators that have a combined capacity exceeding 1MW. The company is registered for and claims ROCS. The greater part of this company's revenue comes from gate fees. As discussed in 3.7.5 on page 40, once a company is structured as a waste treatment operation, having passed the various demanding requirements for the animal by-products regulation, the opportunity to charge gate fees rises considerably. This does not come without cost. The Managing Director is keen to point out that anybody looking to become accredited to handle such waste would need to restructure the business. This is the point at which a farm with an AD operation becomes a waste management operation.

6.2.3. Business Development

Since this case study was first written, Biogen has opened a second digester. The two are the only two in the UK licensed to process Category 2 animal by-product materials. It is possible that in 5 years, BIOGEN will have an electricity generation capacity of 15MWe or more.

BIOGEN has a manager, site operatives and also a full time business development manager, seeking out opportunities to copy the business model throughout the UK. It is looking either to rent farm space in suitable locations or enter joint ventures with farmland owners. BIOGEN is operating a high profile operation, being officially opened by HRH the Princess Royal in September 2007 and even having a visit from the scriptwriters of The Archers!

Surplus heat is not being made good use of. There is sufficient generated to connect into buildings and developments to benefit from it but at present the incentives to do so are lacking. Any available capital has a greater return in other investments than harnessing the surplus heat so this is a rational business decision given the current lack of a renewables incentive for heat in the UK.

6.2.4. Lessons from BIOGEN

The key message that should come out of this case study is that as soon as the feedstock steps from on-farm and green waste to animal by-products, the complexities of the whole operation become magnified. There is no half-way-house, as not only are additional pieces of machinery required, but the management protocols and control mechanisms implemented to guarantee there is no possibility of material escaping from the procedure are tight and demanding.

Whilst the economics of this operation are not available, it is clear that the business structure is quite different from purely on-farm AD plants. Not only is the electrical capacity 2- 3 times the size of most on-farm systems, but the focus on imported feedstocks makes for a different style of operation. The decision to go down this route should be taken carefully.

6.3. THE CENTRALISED DANISH SYSTEM (2008)

6.3.1. Background

The Danes have thought through the concept of centralised cooperation to a far greater level than many other nations, certainly the British. Not only do most farmers in the country operate through cooperative groups for purchasing and sale of their inputs and outputs but also the concept of sharing a resource is something that this country has rehearsed and developed. There are more, larger and successful centralised AD plants in Denmark than the rest of the EU, but also, and more fundamentally, shared heating.

It is commonplace in Denmark for several houses in one vicinity to share a single water heater. To do this, a single ‘central heater’ provides piped hot water into each household to both heat the house and also provide hot water. In other words, instead of having metered gas and cold water mains, as in the conventional UK home, Danish homes have metered hot and a cold water mains pipes and no gas mains. This does mean they cannot have real/fake gas fires in the lounge or gas hobs without the use of tanked gas, but it does mean they can benefit from harnessing heat from power stations as well as electricity. More heat is produced during electricity generation, than electricity. It is understood that this heat is generally wasted in the UK. Having a single system to heat large numbers of buildings also means that a hot water pipe connected from a conventional electricity generation plant or indeed a CHP generator powered from a biogas plant can be easily plugged into a useful market.

Denmark first took an interest in Anaerobic Digestion in the late 1970’s and maintained this curiosity through to the mid 1980’s based on the threat of an impending oil crisis and threats to energy supply. From the mid 1980’s, the Danes became more interested in AD as a partial solution to nutrient losses from agricultural land and the government implemented a Fresh Water Action Plan. This was in fact a precursor of today’s Nitrates Directive that every Member State has to abide by. Renewable energy was also rising up the political agenda. Since the mid 1990’s, the concept of green house gas emissions and the sustainability of livestock production have been addressed through the application of AD.

Throughout the early days of Danish interest in AD, several farm scale plants were established. They were though too small and were not successful. Throughout the decade from 1998, 21 centralised AD operations were established. All but one is still in full operation today. Since then only one more has been constructed (2006). They were established with the benefit of a four pronged support policy:

1. Government investment grants of up to 40%,
2. A monitoring programme that analysed the economic performance of each one
3. Exchanges of experiences between the plant operators with seminars, working papers and regular meetings. This was a crucial part of the programme and often underestimated. The Danish combined cooperative approach was invaluable at this stage.
4. A research and development programme to follow up issues raised by the operators.

From 2000 to 2002, an investment grant was available for on-farm AD operations. Over that period, 50 on-farm AD plants were constructed.

Today, as Table 9 on page 21 indicates, Denmark has about 60 on-farm AD operations and 20 centralised ones. They are all economically viable, but co-digestion (not just manure) is necessary in every case. They sell their electricity to the national public power grid, and the heat is sold to the local municipally owned heating operator. It has been suggested that another 50 CAD plants in Denmark would be viable. Some have set targets to have these constructed by 2025. The Danes would then be using up to 80% of all available manure (they have some cattle 100% housed). To achieve this, an investment grant would be required, as the costs of construction have risen sharply. It is also seen as an opportunity to support the rapidly contracting pig industry.

6.3.2. Two Example Operations ~ Ribe and Lintrup

Two centralised AD operations relatively close to each other (12 miles) provide information for this joint Case Study, Ribe and Lintrup. They are both large operations in the West of Denmark near Esjberg. They process 420 and 547m^3 feedstock per day respectively on sites little more than 3 hectares each. The owners of both these plants are the farmers who supply the manure for digestion. Additional feedstock is taken in both cases (abattoir and fish processing wastes with some sewage too). The digestate is returned to the farmer members, any surplus being sold to other local farmers. Both digesters are at thermophilic temperatures meaning pasteurisation occurs.

The Lindtrup plant was designed as a 354 tonnes per day capacity mesophilic digester in 1990. However, in 1999, it was converted into a thermophilic plant, increasing its capacity by 50%, as throughput could be accelerated. This is now one of the largest AD plants in the world. The biogas is piped via low-pressure piping about 4km at Ribe and 7.5km in Lindtrup to the CHP generator, near the edge of town illustrating that gas can be moved more easily over long distances than heat. The Ribe site does not own or operate the CHP plant, which is dual supplied with biogas and natural gas, although the biogas has first supply priority. The Lindtrup cooperative operates the CHP plant itself.

Table 26 ~ Physical and Financial Data on 2 Typical Danish CAD Plants *(1DKK ≈ 10p)*

CAD (1998 data)	**Ribe**	**Lindtrup**
Year of Construction	1,990	1,990
Biomass m^3/day	420	354
Biogas Production '000m^3/day	4,762	3,718
Manure Suppliers	79	66
Investments '000DKK		
Biogas Plant 1	28,950	32,310
Vehicles	3,700	3,060
Digestate storage 2	12,600	2,380
Separation facilities	0	5,800
Total Investments	**45,250**	**43,550**
Financing '000DKK		
Investment Grants	17,700	16,830
Grants percentage	39	39
Loans	24,750	26,720
Own Capital	2,800	0
P&L '000DKK		
Sales	9,534	8,824
Costs	5,680	5,367
Net Income	3,854	3,457
Physical Data (present data)	**Ribe**	**Lindtrop**
Animal Manure t/day	352	410
Organic Waste t/day	68	137
Total Feedstock t/day	420	547
Biogas Production '000m^3/yr	4,800	5,700
Yield per tonne feedstock m^3/m^3	31.31	28.55
Digesters Capacity m^3	3 x 1745	3 x 2400
Process Temperature	53^{o}c	53^{o}c
Gas storage capacity m^3	1,000	1,000
Distance gas piped to CHP	11Km	7.5km
CHP electrical capacity	sold as gas	2037kW
CHP heat capacity		2600kW

1 including digesters, all storage, CHP and pipelines
2 on-farm storage

Centralised AD has some economic restraints. Firstly, by definition of the business structure, virtually all feedstock and digestate are transported on wheels. This is clearly a very high cost. It means that the furthest farms are the dearest suppliers and that back loads are imperative every time. This is not difficult because a lorry drops a load of digestate on arrival at the farm then collects a load of slurry. Also, in order to optimise the economics, large, 30 tonne tankers are used in all but the most unusual circumstances. Dewatering is a concept that the Germans are using on large-scale operations like this (at a cost of £25 per wet tonne), but the Danish system has not adopted this technology at all.

Another potential problem is growing for the Danish biogas industry. Most plants have a single customer for their biogas or their heat and electricity. Electricity and heat generators tend to prefer to source their fuel from natural gas, being a single and simpler source. The CAD systems operating an open accounting book which means the customer knows their profitability. Having no other customer or potential customer, this gives the CAD business particularly weak negotiating power and they are now generally paid the minimum guaranteed price for their fuel or electricity.

Some people are calling for Denmark to develop a biogas for road fuel industry to overcome this issue, but others feel this will divide the industry, rather than creating new opportunities.

6.3.3. Economics

Contrary to the situation in the UK where the Landfill Tax and the lack of organic waste removal outlets are placing a minimum price on waste disposal, the potential for gate fees in Denmark is much smaller. Indeed, in some regions, the competition to take on other peoples ‘waste’ means gate fees are only worth about £5/tonne (the average is £12/tonne). Nevertheless, as most organic wastes have considerably higher gas yields (anything up to 1,000m^3/tonne compared with about 20m^3/tonne from manure), and with high prices making grain less attractive as feedstocks, Danish AD plants take them. Centralised AD plants are legally allowed to take as much as 25% by volume of organic waste, the rest being farm sourced. This maintains the minimum standard for the digestate spread on farmland. Above this threshold and the regulations regarding digestate change considerably.

A list of the benefits and drawbacks of Centralised AD is discussed in paragraph 3.5 on page 31, most of which is drawn from the Danish experience. The economics of Ribe and Lindtrup are laid out in Table 26.

6.3.4. Lessons from the Danish CAD Model

Lessons can be learned from the Danish Central model. Firstly, they are proven to be economically and technically viable, having been operating for 18 years. It is also clear from these operations that the focus on utilising heat can be profitable, even if it means piping the gas or the heat through insulated water pipes for several miles. The farmers are fundamentally committed to the business by having a financial share in it but their involvement is very simple. The farmer suppliers have no ongoing management requirement at the plant.

Cooperation is important to make things work smoothly. This is seen in the smooth running of a large AD plant and also the evaluation and development of a novel and fledgling industry. The UK is now at the stage of AD development that Denmark was 15 years ago.

Particular thanks to Kurt Hjort-Gregersen, Danish Biogas Plant Association, c/o Bioenergy Centre, University of Southern Denmark for the above Section for generously sharing his time and knowledge

6.4. BENT PEDERSON ~ THE ON-FARM DANISH SYSTEM (2008)

6.4.1. Background

Bent Pedersen is a second-generation pig farmer in central Jutland, Denmark. Over the last 15 years, he has built up his breeding herd to 1,500 sows and weans about 40,000 piglets to 35kg per year (about 12 weeks). This means the farm houses approximately 10,000 pigs at any time. Whilst Mr Pedersen is a landowner of considerable hectarage, all but 200 hectares of this is let out to other farmers meaning he has insufficient land within his holding to spread the pig manure. This number of pigs leaves him with over 12,000 cubic meters of pig manure every year to deal with. Before his AD plant was built, the manure was spread over his land, and that of his tenants, as part of the agreement of farming his land.

Mr Pedersen is a practiced entrepreneur in its purest sense, with the ability to calculate the value of a risk; he has the strength of mind to invest time and money into ventures that appear to offer greater opportunity than exposure. He became interested in AD when a government grant scheme was available to reduce the initial investment cost of AD (which has subsequently now closed). This scheme was similar to the UK's Rural Development Grant Scheme, but more specific to AD and of a lower value. Whilst he made attempts to generate support for a centralised AD operation, involving several local farmers and other waste stream providers, there was insufficient interest. He decided to invest alone.

6.4.2. Mr Pedersen's Biogas Plant

In 2002, Mr Pedersen built a 1,000 cubic meter digester, and installed a 160kWe CHP generator. He spent DKK5.0 million (Danish Kroner), equivalent to £500,000 of which DKK150,000 was reimbursed from the grant. Very soon, Mr Pedersen realised this was not offering sufficient capacity so built another larger digester and installed a second generator (much larger at 350kw) giving him his present capacity of 4,000m^3 digester volume and total CHP generator capacity of 500kW. Total expenditure came to DKK 7.3 million after the grant assistance:

- Initial investment: DKK 5.0 million (of which DKK1.5 million was grant funded)
- Increased digester capacity DKK 2.0 million
- Larger generator and housing DKK 1.8 million
- Total investment DKK 8.8 million less DKK1.5 million grant making DKK 7.3 million (about £730,000) overall

The digester is fed 35m^3 of pig manure every day. At a low gas yield of only about 15m^3 per 1m^3 manure, this is insufficient to generate enough return on the capital invested so 'biodiesel fat' (glycerine) is bought (imported from Sweden) and fed at a high rate of 12% meaning approximately 5 tonnes per day. Also, about 2 tonnes per day of maize silage is fed into the digester in order to balance the feedstock, preventing the high oil mixture from foaming. In total, in excess of 40 tonnes of feedstock is fed into the digester every day. At around 800m^3 per tonne of glycerine, a single tonne of glycerine will be yielding more gas than the entire 35 tonnes of pig manure. Indeed, the manure will be about the same as the 2 tonnes of silage.

With 4,000 cubic meters of capacity, feedstock is held on average for approaching 100 days. At the time of visit, only the 3000m^3 digester was operating, bringing the digestion time down to about 70 days, still a considerable time and allowing capacity for other 'non-farm' feedstocks to be incorporated or for the pig enterprise to grow, should the economics of commodity pig production return.

The digestate is spread over the farmland in exactly the same way that the pig muck used to be. However, the tenants on his land are in fact very pleased with the change from pig manure to AD digestate because it has improved the performance of their crops. Also, the local residents are far happier, as spreading 12,000 tonnes of pig manure used to meet local resistance if spread in non-ideal conditions. With digestate, whilst there is an odour whilst spreading, it only lasts an hour.

6.4.3. Economics

The present system generates 5,000m^3 biogas per day, enough to potentially produce over 8MWh electricity. This is equivalent to an average gas yield of about 125m^3 per 1m^3 of feedstock. Mr Pedersen sells electricity to the national grid for DKK60 cents per kWhe, equivalent to about 6p/kWhe. This is a guaranteed minimum price for renewable electricity for a minimum of 10 years. It is the same price as business-rated electricity, but far less than private houses are charged as this includes additional tax (DKK1.8/kWhe or 18p/kWhe).

The major operating cost is the feedstock charge at about DKK 1 million per year. After this, other operating costs are around DKK200,000 per year.

Table 27 ~ Economics of Danish On-Farm Project

Income *(£1 ≈ 10DKK)*	**DKK**	**£**
Electricity	3,240,000	324,000
Costs		
Capital Amortised DKK7.3m @ 7% for 10 years	1,040,000	104,000
Feedstuffs	1,000,000	100,000
Other costs and overheads	200,000	20,000
Total Costs	2,240,000	224,000
Profit	~ 100,000	~10,000

The capital costs in this situation are lower than one would expect for most cases in the UK in 2008. This is partly because the number of plants in Denmark is considerably higher so construction companies can benefit from a greater efficiency of scale. Also, whist it is a high quality plant, it is very straightforward with limited sophisticated technology for example, only a single pump moves the digestate around and the control system is robust and unsophisticated. It was built by Lundsby, a company that started out building grain silos (http://www.lundsby.dk/); they are now making efforts to break through into the UK market. Mr Pedersen and his farm staff were involved with a large proportion of the construction themselves. Lastly, since this was constructed, although inflation has been low, a construction boom and surge in commodity costs such as power and steel means the construction has risen faster than RPI.

6.4.4. Opportunities and Limitations to develop the Business

Mr Pedersen does not let his entrepreneurial streak rest. He is now focussing his attention towards capturing high value out of the heat generated from the CHP. In 2008, he planned to build a 1.6km (1 mile) highly insulated water pipe running from his farm to his nearby town (large village with a population of roughly 3,000). This would connect to a central town heating system (see previous case study) to pump hot water from his CHP plant to provide hot water and heat for up to 130 houses in winter and about 550 in summer. This will cost Mr Pedersen DKK 2.8 million (£280,000) and will generate an annual income of about DKK 1.4 million (£140,000). Operating costs will be comparatively low (one pump and hopefully minimal maintenance costs) meaning that payback will be about 2 years! His total capital expenditure will by then have reached DKK 10 million (£1 million).

Mr Pedersen is concerned by the rapid recent rise in demand for glycerine. He considers this the greatest threat to his AD venture at present because, not only is it beyond his control, but he has seen the glycerine price double in recent months and availability become more difficult. If this supply dries up, he is not sure which way he will take the business. This is the key factor that prevents him from expanding the capacity of his business in the future. He also notes that he would not be able to construct the plant now as the capital grant scheme is not available, he says he was fortunate with his timing.

Another limiting factor that is becoming an issue is the capacity of the nearby land to spread the digestate. It is piped to tanks that are located on the land on which it will be spread during the periods when spreading can take place. One tank that he is using occasionally is 25 miles away, meaning the digestate has to be tankered. This is extremely expensive. Mr Pedersen sees this as a last resort.

As already explained, the system does hold additional capacity and Mr Pedersen is in negotiations with local businessmen to incorporate a third party waste stream into this plant. It is well located so lorry movements should have a relatively low impact on local residents, and whist he considers at the moment that animal by-products are a step beyond his short term business intentions, 'green waste' is a promising opportunity to add value.

6.4.5. Lessons from Mr Pedersen

To make an enterprise a success, you need to be genuinely interested in it. This way you will be focussed on always improving its performance. This is true also for anaerobic digestion.

Whilst on paper, it only takes a month or two to fill a digester, warm it and create the environment with the correct microbes and generate acceptable levels of biogas, Mr Pedersen points out the start phase takes about a year. This includes all the teething issues, the steepest part of the learning curve and what to look out for and what to do when something goes wrong.

A properly functional biogas plant takes only an hour or two a day to operate and is not difficult. However, a highly reliable and well-trained member of staff, who shares the interest in the project is the most valuable asset on the farm. This means that when you are out selling pigs, dealing with other business or simply taking a day off, the operation continues to run smoothly. It also provides the platform to discuss problems and major decisions.

6.5. The German System (2008)

6.5.1. Background

Germany has the highest number of biogas plants in Europe, so it is unsurprising that many major biogas firms are German. With their home market plateaued and ours accelerating, several of these companies are developing the UK market. They will bring with them the well practiced German technology, expertise, and know-how. It is therefore useful to note how the German industry has developed.

This case study considers the conventional German model in a UK setting. Figures are partially supplied by one of the largest German biogas companies Schmack Biogas[43]. It examines a 450 cow dairy farm with a considerable amount of added energy crop maize and grass silage. The high silage component of the feedstock warrants a plug flow digester followed by a vertical tank making a two-stage digestion process.

Silage takes longer to digest than slurry (or most waste-streams) so the retention time is high at 55 days. Remember the AD operation is paying for this feedstock, not taking a gate fee so maximising yield per tonne of feedstock is important. The implication of this is higher capital set-up costs required with a larger digester. During the summer months, less slurry will be available so recirculated digestate liquor can be used to ensure the correct microbial balance and level of solids to keep it sufficiently fluid.

The heat required to maintain the mesophilic temperature is about 8% of the total heat generated by the CHP generator. This is far less than many digesters, primarily because being fairly high dry matter (25%), there is less water to heat, and as the substrate remains in the digester for a longer time period than most, it is more a case of maintaining heat rather than warming it up. The other heat can then be sold elsewhere.

6.5.2. The Set-up

This plant is designed to operate for 25 years with minimal stoppage time. All capital cost of the digesters are therefore amortised over 25 years. The CHP plant is likely to corrode more quickly and is scheduled for replacement after half that time.

This case study is designed to digest the following feedstocks:

Table 28 ~ Feedstock for Case Study

	Feedstock Volume		**Biogas Yield m^3/t**	**Total Biogas Production**
Dairy Slurry	450 cows,60l/day, 200 days	8,000t	25	200,000 m^3
Maize Silage	100ha, 45t/ha	4,500t	200	900,000m^3
Grass Silage	100ha, 40t/ha	4,000t	160	640,000m^3
Totals		**16,500t**	**105m^3**	**1,740,000m3**

A total of 16,500 tonnes of feedstock digesting for on average 55 days will require digester space of:

12,500t / 365days = 45 tonnes of feedstock per day.

45 x 55 day retention time = 2,500m^3 capacity.

The variation in volume throughout the year means the capacity required for ‘peak’ load is higher reaching 2,800m^3. If this biogas is produced very evenly, and all electricity produced is taken by the contracted electricity distributor, then nearly 3,000 MWh electricity should be produced and sold each year. However, 100% efficiency is unusual, so allowing a 90% return, 2,500MWhe are produced and either used to offset the farm’s electricity bill or sold.

[43] http://www.schmack-biogas.com/wEnglisch/index.php

6.5.3. Economics

The digester and CHP facilities cost £1.0 million. The weak pound against the euro has done many favours to UK agriculture when exporting, but importing goods or services from the Eurozone is now dearer. There are additional ‘ground work’ costs that also require consideration, including preparing road and access, connection to the national grid, housing necessary pumps etc and a silage clamp. This enterprise will require a 300kWe generator.

Table 29 sets out the profitability of the enterprise and further exploration of each item is given below:

Revenue: The potential revenue of this operation amounts to £545,000 per year broken down as follows for every cubic meter of biogas:

- Electricity: 2.0kWh e is generated. Each is budgeted at 14.6p taking account of personal use, feed In Tariffs at 14.5p/kWh Revenue = £493,800
- Heat: 2.5kWh t is generated, 10% returned to heat the digester, 10% wasted and 80% sold to a nearby development for 1.0p/kWht. Revenue = £27,800
- Fertiliser value of the digestate at £3.30 for each of the 15,350 cubic meters makes £41,800

Costs: Total costs of the project are £430,000. The two expenses of the system accounting for two thirds of costs in this operation are;

- depreciation (£62,000)
- Feedstock (£212,000).

Depreciation: The system selected in this example can be depreciated over a 22 year period for the biogas plant and 10 years for the CHP generator on a straight line basis.

The Feedstock: The AD plant is paying the costs of feedstock to the farm. If planning consent can be achieved, and other relevant licensing and assurance standards met, supply of third party feedstock, will not only provide gate fee, but reduce the overall costs. This will introduce a number of additional costs, many though will be fixed, thus not rise proportionately as tonnages increase. Say a gate fee of £35 for a green waste was achievable, and a supply of only 30t/week was achieved (1,560 tonnes per year), then not only would it potentially earn £54,600 fees (before additional costs) but also reduce silage costs by £39,000. Say costs overall added £15,000 to the annual operation (licences, additional labour, sorting and some capital set-up to deal with the waste), then the annual revenue would increase by £70,000.

Finance: The finance cost is the result of the high capital set-up. Indeed, operational working capital is not costed into the calculation. This is because the working capital is low, and also payment for the outputs will be regular and frequent (monthly) in most cases.

Some examples of projects from similar sized AD operations show considerably lower capital expenditure. This case study has costed the full expenditures. Depending on an individual’s circumstances, some of the expenditure may already be covered. For example, some farms that are decreasing their livestock numbers to accommodate an AD plant will already have sufficient digestate storage; others might have the land and machinery to produce enough feedstock at far lower costs.

Profitability and Viability: The profitability of this operation is £130,000. The return on the capital invested at 15.2% is higher than it would be leaving it in a bank. The farm now also has many more opportunities to make money from over the next decade, they should be taken. This example illustrates that making money out of biogas, even with FITs or ROCs needn't be a straightforward cash printing machine. Depending on the operator's situation, other savings could be made. This operation is likely to be about the highest cost, lowest margin set-up in the UK (short of digesting just slurry).

This plant would be able to accommodate the slurry of another 200 cattle with minimal change of energy crop incorporation. Going to 650 cows would make the substrate far more liquid. The built capacity would accommodate the feedstock with an average turnover falling from 55 days down to 50 days, still sufficient to extract most of the energy. There is more analysis of this particular case study in the following chapter on Sensitivity. It uses this case study example.

Table 29 ~ Profit and Loss of Dairy Model

Income	**£**
Electricity (% FIT)	£494,000
Heat	£27,800
Fertiliser saving	£42,000
Gate fees	£0
Other	£0
Total Income	**565,000**
Costs	
Energy feedstock	£212,000
Labour & management	£27,000
Plant costs inc. depreciation	£116,000
General overheads	£54,000
Finance	£22,000
Total Costs	**435,000**
Profit/Loss	**130,000**

6.5.4. Lessons from this System

The AD operation that is using entirely farm based feedstocks is a viable option, but may be only marginal. Costs need to be contained at every stage and performance must be pushed at all times. Opportunities to ease the capital burden should be sought out wherever possible, for example, by using existing farm slurry storage. Entrepreneurs should look to capitalise on all other business opportunities available to them. This could include developing opportunities for private wires to local businesses to make additional money from electrical sales and saving connection charges or direct heating systems.

6.6. JENSEN FARMS ~ DEVELOPING A NEW AD PLANT

6.6.1. Background

This case study is a blend of real experiences the author has experienced in the last 12 months combining several farm AD feasibility exercises to highlight some lessons and pointers thus the names are not real. Jensen Farms is owned and managed by Mr. Jensen and his two sons. Each family member has their own separate part of the business to manage. They are an organic beef and sheep farm in the North of England. The farm business is profitable, but as one business objective is to increase stock numbers, much of the profit comes through in the increase in valuation rather than cash return. After drawings and commitments to repay borrowings have been met, there is little remaining for reinvestment.

The business is large in area extending over 2,000 acres (810 ha), divided into two farms, Home farm and the other about 12 miles away. The land is mostly of grazing quality, although some is suitable for grass silage. Maize does not grow well in the area being north and with unsuitable soils. The land, coupled with the farm houses, cottages and livestock buildings provides a relatively large balance sheet for the business. Borrowings are small compared with the balance sheet but repayments absorb most of the profit. The business has a good relationship with its bank manger who is largely supportive of growing their business.

Mr Jensen would like to develop an AD plant on his farm, to:

- Provide a profitable enterprise
- Make use of resources that are available including:
    - labour and management,
    - spare silage land
    - 5,800 tonnes farm yard manure

A new enterprise on the farm should

- fit into the farm system rather than change it dramatically,
- be able to provide a cash flow relatively quickly because, whilst the capital can be supported, it will need to finance its own capital.

6.6.2. Technical Options

The feedstocks available to the farm are as follows:

- 5,800 tonnes of farm yard manure of about 27% dry matter. This is effectively free feedstock but would need lots of chopping as it contains a high proportion of straw.
- Possibly up to 2,500 tonnes of broiler manure of about 30% dry matter. This would cost £12.50 delivered onto farm so would cost the operation £31,250. The farm is already buying this to use as an organic fertiliser, so the cost is at least partially offset by the benefit to the farm system.
- 52 hectares for grass silage (at 38t/ha) so 2,000 tonnes. The cost of producing this is budgeted at £25/tonne so costing the AD enterprise £50,000 payable to the farm business. Whilst this adds a

return to the farm, it also removes some of the best forage land from the livestock rotation. As the farm is also trying to build livestock numbers, this might lead to having to rent additional hectares locally or buy-in silage from elsewhere.

There are several systems available to digest feedstock of 30% dry matter, but most are dearer than the wet digesters in relatively small volumes. This plant would require a digester of about 1,700 cubic meters (with a 60 day retention period) with an electrical capacity of about 170kWhe. This does potentially make a profitable system but finding the technology to cope with this is difficult. Adding enough water to bring it down to 15% would not only cost a lot to source and heat the water but would double the required capacity of the AD plant to 3,400 cubic meters. This would become too costly for the feedstock in question.

Another option for the AD plant is to consider other sources of third party waste as a feedstock, potentially raising the total feedstock tonnage, lowering the dry matter content and even gaining a gate fee to help cover the additional costs. A telephone based enquiry was made to local waste management companies and other organisations likely to have significant amounts of organic wastes to dispose of. One organisation was interested but could only offer 'a few hundred tonnes' of category 3 ABP wastes, and another company was very keen to supply a lorry load a day but it transpired he had not won that contract himself yet. No investments can be made on the back of that! The search continued but Mr Jensen and his sons were aware that a waste processing facility might change the feel of the business completely (and possibly lose the contact to supply beef and sheep to a major supermarket outlet). This is not necessarily out of the question, but the supermarket's relationship has been a strength of the business over the last 5 years.

Notwithstanding the question of how the plant might alter the shape of the existing business, if it makes it far more profitable it should be considered to identify whether the entrepreneur's other objectives can be fitted into the business plan. Continued searching and time spent building a network of contacts within the waste sector in the vicinity eventually identified a series of other interested parties, between them potentially adding up to a minimum tonnage in excess of 10,000 tonnes a year. This is equivalent to a lorry load a day.

Suddenly with this potential feedstock, the moisture levels are likely to be higher, the biogas yields higher and the volume of feedstock doubled. Indeed, the expenditure on the poultry manure might not even be necessary. Not only did the total feedstock and therefore throughput figures change dramatically at this point, but also the technology providers, the complexities of relationships required with the equipment suppliers and the capital sums in discussion.

Planning moves on a considerable distance too. The initial business plan, using solely farm waste, did not require planning consent; simply informing the planning department the agricultural development was going ahead was all that was required. But with importing waste, there are implications for road traffic and neighbouring dwellings, and the planning issues become more complex. Indeed, as there is no such thing as outline planning for a waste processing centre, it was decided to hold a public meeting to raise the awareness of AD so decisions and opinions could be based on informed judgement. Only a very small number of locals made the effort to attend. Other ways of educating the local residents were necessary. Of those who did attend the meeting, there was widespread support for the concept and a plant in the location proposed, apart from one attendee who said that he would oppose any application. This person was the land owner of a narrow strip of land about 500 meters from the proposed plant.

The other issue that becomes increasingly important as the project moves from on-farm to third party feedstocks is finance. As already stated a strong balance sheet is very useful and a good relationship with a bank is also critical, but it raises the stakes because not only are the risks higher, but also the sums required are higher before a single tonne can be processed. The bank is less comfortable with the new level of exposure and whilst there was no flat refusal of support, Mr Jensen felt it might be prudent to cooperate with an organisation that has more experience with waste management processes.

A nearby business park manager shows an interest in buying the electricity (and potentially heat). The complex is positioned about 500 meters away as the crow flies. The electrical connection at that point is privately owned and information about its capacity is easily available. However, between this and the most suitable site for the CHP plant is a river and railway line. This is not an insurmountable obstacle as engineers can bore under them. It will, however add considerable cost to the operation. The next nearest connection is about 400 meters in another direction. The DNO declined to say what electrical load this network could carry, citing technical reasons and couldn't state whether the line had spare capacity for additional electrical charge. This makes the cost estimate particularly vague and any kind of planning is difficult without knowledge of the capacity it can supply.

It emerged that the buyers of the beef and sheep would be very happy to continue buying the livestock with an on-farm AD plant on the land and indeed purchase the power. However, the concept of adding third party wastes onto the farm changed opinions. Also, it transpired that the farm's organic status, whilst able to accept third party non-organic wastes for digestion, could not accept any waste that had any chance of containing a GM residue. This effectively counts out virtually all food wastes from shops, households and food outlets. On the basis that Mr Jensen wants to retain his organic status, unless sufficient feedstock from a dedicated outlet can be found, this route becomes less feasible.

Recent announcements of the uncertainty of double ROCs and the lower than hoped FIT payments make the economics more marginal. The bank hesitates and Mr Jensen puts the plan on the back burner until confirmation on these rates and State Aid regulations are clear.

6.6.3. Lessons to Learn from Mr Jensen's Case Study

This Case Study illustrates that AD might not be entirely suitable for every farm system in the UK. This farm has a useful set of feedstocks to utilise but probably not enough or the right blend. Time spent identifying the right technology for each situation is highly valuable, the difference between two AD systems is equivalent to the difference between a sugarbeet harvester and a combine harvester rather than the difference between two makes of tractor. Also, detailed examination of each technology helps to identify which providers have the expertise and knowledge to identify the correct solution, some are keen to make sales, others to ensure the right technology is used. We can also learn from this case study that dealing with the local Distribution Network Operator is usually difficult. Any electricity generator of less than about 50MW capacity is considered small.

Another key and possibly most important lesson is that an assessment of viability of an AD plant on its own, that takes no account of the impact of the new enterprise on the rest of the farm business or existing enterprises is potentially dangerous. Partial budgets can be risky tools to use in isolation in these situations but, when accompanied by either a full business budgeting analysis including a capital appraisal or a 'heads-up' assessment of how the enterprises might link together, they provide useful information.

The introduction of an AD plant on a farm business can have fundamental effects on the business as would have occurred here; it would no longer be just a farm business. Time spent discussing what the farmers really want to achieve is important. In this case, whilst the waste management facility option might have returned a higher profit for the family, it might not have led to a greater level of personal satisfaction than farming in financially tight but rewarding conditions. It encouraged the farming family to examine their own personal objectives closely.

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7. SENSITIVITY ANALYSES

Chapter Summary

- Businesses need to test their plans against extreme movements in the economics within which they operate
- A 5% change in efficiency creates the biggest difference to profitability
- The second biggest sensitivity is feedstock volume. The effect on profit is smaller, as some costs are offset.
- Sensitivity tests not only expose the risks to an investor but also identify where a manager should be spending most time

All business ventures have to be robust within a range of variables. The moving economics of agriculture, other commodities, energy supply and finance expose ventures into AD to large movements in potential return. Input and output prices and performance criteria should be examined to understand their sensitivity on profit. The spreadsheet illustrates the effects to your own figures, but as an indication, the effect of movement of five key variables is studied here. The Case Study 5, 'the dairy farmer' is used for the analysis. Each variable is tested against the effect on the profitability of the operation and also the *Gross* Return on Capital. This is the profit plus the finance divided by the total capital:

7.1. COSTS OF FEEDSTOCKS

In this particular case study, the cost of feedstocks accounts for almost half of all costs. This system buys in energy feedstocks (from the rest of the farm). The average cost per tonne is £12.87, some (the slurry) is effectively free.

Figure 10 ~ Sensitivity on Changing Feedstock Cost

Percent Change	Feedstock Cost	Profit	Return on Capital
-100%	£0.00	342,060	36.41%
-20%	£10.30	172,060	19.41%
-1%	£12.75	131,685	15.37%
Feedstock Cost	£12.87	129,560	15.16%
5%	£13.52	118,935	14.09%
10%	£14.17	108,310	13.03%
20%	£15.45	87,060	10.91%

The table illustrates how the feedstock is clearly an important cost, as its movement makes a major change on profit and return on capital. For every 1% price change, profit moves by about £2,125.

Replacing high cost energy crops with a third party 'waste' would cut feedstock costs swiftly, probably replacing them with a revenue stream. This is how a 100% cost change can be achieved, some might even go further, if a revenue can be generated from them.

7.2. Output Price Movement

7.2.1. Electricity

Electricity is the major value output. No costs are affected. One penny per kWhe increase in the PPA contract is equivalent in this example to over £33,410. Maximising a good contract that you are confident of being able to supply is therefore highly important. It is also worth knowing the penalties of missing the supply obligations within your contract.

Figure 11 ~ Effect of Changing Electricity Price

Percent Change	p/kWh e	Profit	Return on Capital
-20%	11.69p	30,791	5.28%
-10%	13.15p	80,176	10.22%
-5%	13.88p	104,868	12.69%
Average Price	14.61p	129,560	15.16%
5%	15.34p	154,252	17.63%
10%	16.07p	178,945	20.09%
33%	19.43p	292,529	31.45%

7.2.2. Heat

The situation for heat is similar but has a lesser effect being a lower value output:

Figure 12 ~ Effect of Changing Heat Price

Percent Change	p/kWh t	Profit	Return on Capital
-20%	0.80p	123,992	14.60%
-10%	0.90p	126,776	14.88%
-5%	0.95p	128,168	15.02%
Average Price	1.00p	129,560	15.16%
5%	1.05p	130,952	15.30%
10%	1.10p	132,344	15.43%
33%	1.33p	138,747	16.07%

Whilst the revenue from selling heat is likely to be smaller (and may incur additional costs that don't show up in this case study), this particular example earns just over £13,900 by increasing its heat sale price by half a penny per kWht. We note, in this particular example, only 80% of the heat is actually being sold (reflecting the likelihood that selling all heat may be difficult to achieve cost effectively).

Neither this report nor the spreadsheet examine what happens when both electricity and heat prices move together. This is not unlikely.

7.3. CHANGING FEEDSTOCK THROUGHPUT OF A FIXED CAPACITY PLANT

Figure 13 ~ Profit Sensitivity of Feedstock Capacity Change

Percent Change	Feedstock Tonnage	Profit	Return on Capital
-20%	13,200	59,202	8.12%
-10%	14,850	94,381	11.64%
-5%	15,675	111,971	13.40%
Budgeted Tonnes	16,500	129,560	15.16%
5%	17,325	147,150	16.91%
10%	18,150	164,739	18.67%
20%	19,800	199,918	22.19%

Figure 13 highlights how easily a marginal decrease of throughput can very rapidly turn an enterprise, which is profitable on paper into a financial nightmare! A breakdown will put pressure on the rest of the financial year if it is not handled efficiently and effectively. Increasing throughput without affecting overheads or yield has a direct impact on the return. In simple terms, the last tonne digested will be the cheapest to produce, or looked at from the other way, as long as yields don't fall, will return the greatest profit.

7.4. CHANGING EFFICIENCY OF CHP OR GAS CREATION

An operation that is 100% efficient is

- making full value from all of its resources,
- not capable of increasing its output without losing revenue
- fictional!

There is no such thing as 100% efficiency. Sooner or later, some repairs are required. All businesses have a first limiting resource, one thing that limits the operation of the rest of the business. This is resource inefficiency. At any time, the limitation for any business could be capital, labour, management ability, communication, land, or machinery to name but 6 common examples in agricultural businesses.

A 1% change in efficiency changes the output of this case study by £5,692 (less a few saved variable costs). This would represent only 3 days down time in a year. The figure shows the impact of a considerable drop in efficiency, for example if the CHP was operating at poor efficiency for most of the year, or a substantial biogas leak went unnoticed. It reminds us of the value of checking the key management and operational data on a regular basis! Keeping the gas production at its highest yield and the CHP generator operational as much as possible is clearly critical. Some plants operate at only two thirds of its potential, clearly losing money. Others claim to reach levels as high as 97%.

Figure 14 ~ Operational Efficiency

Percent Change	Efficiency	Profit	Return on Capital
	70%	15,719	3.77%
	80%	72,639	9.46%
	85%	101,100	12.31%
Budget Capacity	90%	129,560	15.16%
	95%	158,020	18.00%
	100%	186,481	20.85%
	105%	214,941	23.69%

7.5. CHANGING CAPITAL EXPENDITURE

As already discussed, capital (and its associated finance costs) accounts for one of the largest costs in a biogas plant. In this example, it is the second largest.

Figure 15 ~ Capital Effect on Cost of Production

Change	Capital	Profit	Return on Capital
-20%	£800,000	149,460	21.43%
-10%	£900,000	139,510	17.95%
-5%	£950,000	134,535	16.48%
Budgeted Capital	£1,000,000	129,560	15.16%
5%	£1,050,000	124,585	13.96%
10%	£1,100,000	119,610	12.87%
20%	£1,200,000	109,660	10.97%

The effect on profitability of changing the initial capital expenditure may appear relatively modest compared with some of the other variables. In this case, a 1% change in capital expenditure (£10,000) represents a change in annual profitability by £1,000. It is relatively small but this cost change remains with the business until the capital has been paid for, which could last 25 years i.e. £25,000. A price fall in electricity, or a downturn in production because of mechanical breakdown is a nuisance and very costly for that year, but should not impact on subsequent financial periods apart from moving the opening bank position. Carrying high levels of capital items takes longer to overcome, let alone the additional burden of repaying the liabilities used to purchase them in the first place. Such is the power of compound interest.

7.6. SENSITIVITY SUMMARY

The above sections illustrate how much business profitability can move by some relatively small changes in prices and physical performance. Table 30 summarises the sections showing the effect on profit of a 5% change of the key variables measured.

Table 30 ~ Effect of a 5% Rise of Key Variables

Variable	Change of Profit
Cost of feedstuff	-£10,625
Electricity price	£24,692
Heat Price	£1,392
Throughput of feedstock	£17,590
Efficiency of plant	£28,460
Capital expenditure	-£4,975

This table illustrates how the efficiency of an AD plant is so important. It includes the utilisation of feedstock, capturing maximum yield, and converting it to electricity without leakage, downtime or other losses. It is more important than simply feedstock throughput because a lower feedstock throughput in this AD system would also save feedstock costs. In summary, each of the particular variables explored need close management in order to keep profitability as high as possible This should highlight to the management where the bulk of management time needs to be spent.

8. BIOGAS INJECTION INTO THE NATIONAL GAS GRID

Chapter Summary

- Cleaned biogas (removed carbon dioxide, sulphate compounds and other gasses and filtered for particulates) is called biomethane. It is at least 96% methane.
- Biogas injection into the National Grid is currently not viable without financial support.
- The Renewable Heat Incentive should change this in 2011.
- Biogas used in place of natural gas provides many benefits and might prove the most efficient use of the resource.
- The cost of setting up the facility to clean biogas into Biomethane is a major investment.

Generating electricity from biogas without capturing the full benefit of the heat simultaneously produced has an efficiency of as low as 30%. Until now, there has been no incentive to invest capital to save and use heat efficiently as it has been worth so little (1-2p/kWht). Methods of transferring heat have been used such as piping it in highly insulated hot water pipes to district heating networks, refer to the Danish Case Studies (Pages 84 and 87). But if a site is already built, retrofitting[44] a network is almost impossible. Furthermore, most people in the UK are not aware of these systems, let alone ready to adopt them.

Injecting biomethane into the gas national grid network would not affect resident's houses (or workplaces) as the infrastructure is already in place (the pipes) and mostly paid for by existing business and customers. Indeed consumers might not even be aware. As of April 2011, the Renewable Heat Incentive (Page 15) should subsidise the production of heat from biogas, making the choice between electricity production and other uses closer to call. Many consider the replacement of fossil gas by biomethane will eventually prove a more efficient, and GHG saving, option to electricity generation.

Biogas cannot simply be injected into the gas National Grid. It needs purification, removing carbon dioxide (which dilutes the methane), hydrogen sulphide (being corrosive) and water vapour (which lowers the calorific value of the gas), turning biogas into "biomethane". Biomethane is approximately 98% methane. Methane made from biogas purification is atomically identical to natural gas that was made millions of years ago. It can only be differentiated by measuring the level of a less stable form of carbon, C_{14} compared with C_{12}. Its similarity to the gas we already use makes it a simple renewable energy to implement. There is no need to redesign engines or worry about blends as with biofuels.

Better then, where possible to replace fossil gas with biogas in the National Grid. The National Grid in a publication[45] in January 2009 on the matter supports the concept, and states:

> *"There are no insurmountable barriers to delivery. Technically, renewable gas production, upgrade and injection is possible and the upgraded gas will be safe to use in consumer appliances provided*

44 Retrofitting is fitting new technology or features to older or existing systems/properties

45 www.nationalgrid.com/uk/Media+Centre/Documents/biogas.htm

the gas meets the UK specifications set out in the Gas Safety Management Regulations [46]*."*

The National Grid identifies one surmountable issue, that biomethane has a slightly lower calorific value than natural gas. This is a commercial rather than technical issue, so consumers downstream of a biomethane injection point would have their bills adjusted or propane injected appropriately to compensate for the minor energy drop. Gas bills are already adjusted for calorific value of the gas delivered, so this will not create a problem.

8.1. How Much Gas Could be Produced?

The National Grid report considers the extreme. It states that potentially, if all UK biodegradable waste was digested, potentially as much as 50% of residential gas demand could be met. This is what they refer to as their 'stretch' scenario, or situation if 100% of waste was recovered and that this is unlikely, but the point is made. Extreme scenario studies are important but realistic studies of likely implementation would see a fraction of this being achieved. Why? Well, much biomethane is already being used for other purposes which are being more strongly supported; some feedstock is not located in areas suited to economic AD plants and some operators simply won't have the inclination or resources to build an AD plant.

8.2. What is Necessary to Move Forward?

The National Grid report claims a number of changes are required to make biomethane injection into their grid happen on a commercial and wide scale throughout the UK:

- A commercial incentive for renewable gas producers to upgrade their biogas to biomethane.
- A comprehensive waste management policy to ensure all wastes are streamed to their most useful processing site, not land fill or incineration.
- A regulatory framework to incentivise gas transporting companies (network operators) to support biomethane injection
- Continued support for R&D in renewable gas production and upgrade.

The first point is starting to happen already with the RHI redressing the commercial balance of the end use choices between electricity and others.

8.3. Is Biomethane the Big Opportunity for AD?

As yet, the value of the Renewable Heat Incentive is proposed at a value of 4p/kwh t, apparently equivalent to the FIT incentive for electricity generation. If this is the case, then it is likely that an AD entrepreneur would have a genuine choice to make with regards to whether to generate electricity from the biogas or to purify it into biomethane and inject it into the National Grid or cylinder it. This commercial decision will depend on:

- Cost of electrical grid connection
- Cost of gas grid connection
- Ability of the entrepreneur to build a customer base for compressed gas

[46] http://www.hse.gov.uk/gas/supply/gasscham/

- Personal objectives of entrepreneur

The system that makes use of the heat from CHP might be able to claim both the FIT and the RHI. There are some farms that are located in isolated positions, not ideally suited to either electrical or gas connection, or near suitable gas grid connection points but not electrical and vice versa. The cost of these connections is high (in rough terms, the cost of connecting to the gas grid is comparable to that of electrical connection .

A report[47] published in December 2009 by DECC outlines the principles of feeding biomethane into the National Gas Grid. It includes a section on the principles of connection, how to go about it, who to contact and who is already involved in operating the National Gas Grid and parts of it.

8.4. HOW TO GENERATE BIOMETHANE FROM BIOGAS

8.4.1. Standards

There is no internationally agreed standard for biomethane but many countries that are more advanced with their uses for biogas have created their own standard.

- Sweden has had a national biomethane standard since 1999 following a request from the national vehicle manufacturers. This standard is also applied when injecting gas into the national gas grid.
- In Switzerland, biomethane is injected into the national grid. There are two standards, one for limited injection, one for unlimited.
- Germanys biomethane standard (G262) is based on their standard for natural gas. There are also 2 levels for limited and unlimited injection.
- France produced a standard in 2004.

8.4.2. Technology

The most expensive part of cleaning biogas into biomethane is the carbon dioxide removal. Biogas is water saturated so needs drying and the desulphurisation process is equally important as hydrogen sulphide is corrosive. Indeed, for this reason, this tends to be the first part of the 'scrubbing' process.

The most costly aspect of the biogas cleaning process is the capital. Companies are already in position to provide AD plants with the technology to upgrade their biogas into biomethane. The costs of buying and installing the technology in the UK is roughly as follows:

Table 31 ~ Costs of Upgrading Biogas into Biomethane

Biogas production	Total capital Cost	Capital cost per m^3 biogas over 6 years	Comparable CHP capacity for gas volume
Up to $80m^3/hr$	£480,000	11p	140kW
800 m^3/hr	£850,000	2p	1.4 MW
$2000m^3/hr$	£1.7 million	1.6p	3.4MW

[47] *Biomethane into the Gas Network: A Guide for Producers.*
www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/markets/gas_markets/nonconvention/nonconvention.aspx

Guideline figures across Europe appear to be slightly lower than this. However, as this technology is so specialist in this country, one would expect a higher price tag. If its use rises in time, one would also expect its total cost to fall. This installed plant, connecting to the biogas pipe from the top of the AD digester will purify the biogas into biomethane. It would then require either plugging into the national gas grid or bottling; additional costs are therefore necessary before it can be handled.

A report on biomethane will shortly be published by Task 37, a government supported working group acting as an advocate of AD, an information hub, promoting deployment of AD and supporting good practice. It is part of an international network. The Andersons Centre sponsors Task 37.

Thanks to Chesterfield Biogas for their assistance compiling this chapter (www.chesterfieldbiogas.com).

9. BIOMETHANE AS A ROAD FUEL

Chapter Summary

- When biogas is upgraded to biomethane it becomes suitable as a road fuel.
- There are few vehicles in the UK and minimal infrastructure to supply biomethane road fuel.
- Sweden has invested heavily and achieved a small infrastructure for road fuel
- Some other countries have a biomethane strategy.
- On paper it looks efficient and very environmentally friendly but there are barriers to overcome.

Biogas, with all its benefits is clearly environmentally preferable to using fossil fuels in any situation as long as it can be reliably supplied. There is also mounting evidence to suggest that biogas as a road fuel is more environmentally sustainable than any other biofuel. One such piece of evidence is illustrated by the Institute for Environment and Sustainability[48]. Some also suggest it is the most efficient use of biogas. The biogas policies are currently focussed on offsetting green house gas emissions of electricity, but this might not be the most efficient policy.

Theoretically, unprocessed biogas can be used to run cars. However, in a 'raw' state, with 40% carbon dioxide, moisture and other impurities such as hydrogen sulphide and microscopic particulate matter, the energy from the methane will be dilute and the engines would soon become corroded and damaged by the hydrogen sulphide and blocked by the particulates. Vehicle manufacturers are not going to issue warranty for vehicles that have used this in their fuel tanks. The biogas therefore needs to be upgraded to purify the methane into biomethane.

9.1. PREPARING BIOGAS TO BE A ROAD FUEL

This report is not a technical study of the engineering required to 'scrub' (clean) biogas into biomethane, there are some far more detailed studies that cover this[49]. In brief though, the carbon dioxide and impurities can be taken out of the biogas to leave methane in excess of 96% by passing it through water at high pressure (about 7 to 10 bars) as methane is less soluble in water than the other gasses. Other methods using organic solvents are also available. The resulting gas then needs to be put into canisters at 300psi (200 times the pressure of normal air pressure).

When the methane in biogas has been purified, it has the same properties and constituent parts as natural gas (which is also methane) and 1m^3 (normal air pressure) has a roughly similar calorific value as a litre of conventional petrol or diesel. It is therefore a fuel which can supply the Compressed Natural Gas (CNG)

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[48] *Well to Wheels 2007* http://ies.jrc.ec.europa.eu/uploads/media/WTW_Report_010307.pdf

[49] *(e.g.* http://www.sgc.se/uk/index.asp *and* www.environmental-protection.org.uk/assets/library/documents/biogas_as_transport_fuel_june06.pdf

fuelled cars (or indeed the Liquefied Petroleum Gas LPG fleet). Thus, developing a national fleet of vehicles fuelled (or duel fuelled) on CNG is a logical point to begin from to establish an infrastructure to sell this fuel into.

9.2. WHAT'S GOING ON ELSEWHERE?

Clearly, a sufficient infrastructure is required of regional if not national coverage to make travel using this fuel possible. Furthermore, a driver has to see some benefits of converting from (reliable and trusted) conventional road fuels to another, which takes up more boot space to store the gas and requires more frequent refuelling. Whilst the number of these vehicles is small in the UK, there are several cases of new projects globally promoting gas powered road vehicles primarily as an environmental initiative. Examples include[50]:

- Pakistan is opening natural gas filling stations on a daily basis,
- A Californian school district is spending $2.6m (£1.3 million) on new CNG school buses
- Indonesia is spending $50 million on gas vehicle fuelling infrastructure in Jakarta
- Even 'oily' Texas has announced a $5m grant programme to encourage fleets of heavy duty vehicles to run on CNG.

Sweden is pioneering the use of biogas as a vehicle fuel in Europe, having had a growing biomethane road-fuel supply chain since the early 1990's. In 2006, 24 million cubic meters of biogas were used as road fuel, equivalent to roughly 250 million car miles. In fact, 2006 was the first year that more biomethane was used as transport fuel than natural gas. There were 11,500 vehicles powered by biogas and nearly 100 filling stations[51]. Sweden has set a minimum standard for biomethane to ensure consistently high quality fuel is used on the road. Sweden has worked hard and spent considerable sums to create the industry and supply chain infrastructure it has today:

- A 30% investment grant for new plants
- support programme to help assist biogas filling stations
- Biomethane powered company cars have a 40% 'valuation tax' reduction
- Biomethane is exempted from 'excise duty'
- Some cities (e.g. Gothenburg) provide free parking for environmentally friendly cars.
- Others wave congestion charges
- Even the fuel supply companies have agreed to keep the price of biomethane at 20-30% less than petrol whilst the market is still in development phase.

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[50] Extracted from a Paper presented by Organic Power Ltd to the *Bournemouth, Dorset and Poole Renewable Energy Conference* June 2007 www.dorsetforyou.com/media/pdf/3/r/Waste_-_Sue_Akester.pdf

[51] *Basic Data on Biogas Sweden 2007* ~ http://www.sgc.se/

This indicates the degree of commitment needed to achieve an infrastructure of the capacity now available in Sweden.

9.3. UK BIOMETHANE INFRASTRUCTURE

There is little infrastructure for CNG or biomethane fuelled vehicles to speak of in the UK and few vehicles able to run on the fuels. Producing compressed biomethane as a road fuel may only work (particularly at the outset) if there is a known market prepared to commit to buying gas. This implies a fleet of converted vehicles. Focussing your marketing on a bus company was once futile as they had subsidised fuel through the Bus Service Operators Grant (BSOG). However, since April 2009, a change to the BSOG means operators using Low Carbon Emission Buses (LCEBs) which are fuelled by biogas are eligible for an additional 6p/km. Indeed Boris Johnson should take note of this as a mechanism for reducing the air particulate level in London.

Benefits of biomethane over conventional fuels are;

- a reduction of emissions decreasing smell as well as green house gases
- it is considerably quieter than petrol or diesel engines
- nitrous oxide and particulate emissions are lower reducing problems with asthmatics etc.

A fleet company with regular night-time journeys through built up city areas might be a good place to start finding a potential customer. A large taxi company in a big city should be ideal. It is critical however, as far a business risk is concerned, that the contract to supply a customer, especially if a single business is accounting for a large proportion of your sales, to have a sufficiently long contractual period so you don't get left with considerable investment with minimal return.

Getting a new fuel introduced is extremely difficult once a network of existing different fuel supplies is already in place and comparatively reliable and effective. It can be a 'chicken and egg' situation whereby few people are likely to buy a car with little opportunity to refuel. Likewise a forecourt manager is unlikely to supply a fuel if nobody has a vehicle that runs on it. The infrastructure that currently exists is limited in its flexibility. Many of the few existing CNG suppliers only have the facility to fill HGVs, not cars, as the cost of the tanks and nozzles for smaller vehicles is too great in relation to the size of the potential market. However, there are a couple of places where you can refuel a CNG powered vehicle with biomethane in the UK; Hardstaff's lorry park in Nottingham and Organic Power in Somerset. Other companies are becoming more interested in using biomethane as a road fuel, these apparently include Veolia, Warburtons and some of the supermarkets. Some of the water utility companies are looking to convert their biogas plants at their sewage works to generate biomethane instead of electricity. Indeed, Sita, a major waste management company has worked with Gasrec, the UK's only commercial producer of liquid biomethane fuel to open a site in Surrey in 2008.

Trevor Fletcher, the managing director of the Hardstaff Group is convinced the route to progress is to develop the infrastructure as the vehicles are already available in large numbers in other countries (there are already 10 million LNG vehicles worldwide). In order to achieve a new infrastructure, he says, there are five necessary criteria that must be met:

1. Sustainability of fuel supply (is there enough?)
2. Sufficient infrastructure for fuel supply (is it supplied in enough places?)
3. Fuel containment (is the technology to carry fuel developed?)
4. Dealership and supply including a support service.
5. Having sufficient vehicles to use it.

Access to injecting gas into the national grid (ingress) and taking gas from it (egress) is not likely to be an issue to small scale users as most households already have connections to the national gas network. However, for larger users, such as those wanting to supply biomethane as a road fuel, this has been cited as an issue. London has the most developed underground gas network of any city in Europe but is still appears to be a problem to find a suitable location to position a fuel station that has sufficient access to fuel vehicles from it. Also, some comment that the ingress of moisture is making the extraction of gas from mains to use as a road fuel somewhat of a problem.

9.3.1. Vehicle Types

There are three categories of technology that can run on biomethane,

- **Dedicated engine**; a spark ignition engine that runs only on biomethane/natural gas. It is quiet and has low emissions. These engines are more common on heavy and light duty goods vehicles.
- **Bi-fuel engine**; spark ignition (petrol) engine adapted to also run on biomethane, i.e. it has the ability to run on petrol as a back-up fuelling system but not both together. Quiet with low emissions when running on biomethane. This is more common on smaller vehicles.
- **Dual fuel**; Compression ignition (diesel) engine, engine adapted to operate on a mixture of gas and diesel. Up to 80% gas substitution is achievable but can still operate solely on diesel. Adaptations are available as retrofit. This technology is already 50 years old, originally designed for use in the shipping industry. It is currently available for 7½ to 44 tonne lorries and buses.

So what is the additional cost of the vehicles? It varies according to the size of the vehicle and the tank capacity (the more fuel tanks fitted, the further it will be able to travel between refills). This is a guide to the additional cost above conventional vehicles:

Transit size van	+ £3,500-£5,000
Small Lorry	+ £14,000 -£20,000
Large lorry	+ £25,000
Waste collection vehicle	+ £21,000

9.4. THE OPPORTUNITIES OF BIOMETHANE FOR ROAD FUEL

Government incentives to encourage renewable road traffic fuels are explained on page 14. The costs of upgrading the biogas into biomethane are very high, and would only be justifiable on a large-scale digestion plant and a "purifying" facility. This then presents problems in terms of obtaining a robust contract with a vehicle operator or fuel supplier to purchase the vast amounts of gas needing to be purified to make any investment viable. However, there are companies that have achieved it and built a circle of drivers to depend on either the gas supply or other natural gas fuel supplies. In the UK, this will take a considerable commitment to achieve at the moment.

A report published in 2005 (when fuel prices were considerably lower) considering the Irish situation[52] showed that a cubic meter of biogas would generate 0.57m^3 biomethane, roughly equivalent in calorific value to 0.57 litres of petrol. At that time (April 2005), petrol in Ireland was costing about €1/l, or €0.57 per 0.57 litres. The same amount of biogas produces 2.0kWh electricity worth at the time in Ireland about €0.16. In other words, the additional revenue potential from selling compressed biomethane is approaching four fold. Doing the same calculation under UK conditions for December 2009 comes up with the following results:

- Total revenue per m^3 biogas from CHP including FIT = 30p/m^3 biogas
- Total revenue per m^3 biogas from road fuel excluding RTFCs = 42p/m^3 biogas
- Additional revenue per m^3 biogas from road fuel option = 12p/m^3 biogas

This is a single case study and takes no account of any additional costs required to achieve the very high level of gas purity, or the costs required to bottle and market the finished product. Other costs such as public liability insurance will go up significantly too. The excellent Environmental Protection Association report (www.environmental-protection.org.uk/assets/library/documents/biogas_as_transport_fuel_june06.pdf) suggests that biomethane could be produced for about 50-60p/kg in 2006 (including duty but excluding VAT), not dissimilar to the then CNG forecourt prices before VAT. CNG prices for use in HGVs are quoted at approximately 65p +VAT per kg (at the time of writing). This sort of cost though, not only removed that margin potentially available for biomethane over biogas use in CHP, but clearly removes all profit from the example figures used above. As the Renewables Obligation offers two certificates per MWh of electricity provided from AD, one would logically understand if double certificates were to be provided for road fuel from AD too. This could have sufficient impact to start growing a biomethane industry and infrastructure in the UK.

To compare the cost of biomethane with conventional fuels, it is best to compare them per kilometre or mile. The following table illustrates the cost comparisons. Initially, the biogas appears far cheaper with lower costs per mile for the fuel. However, the vehicles are more expensive to buy, or convert.

Table 32 ~ Comparison of Economics of Road fuels

	Biomethane VWG van	**Diesel Van**
Fuel Price	65 p/kg	113 p/L
Fuel Consumption	17 km/kg	45 mpg = 16 km/L
Price per km	**3.8 p/km**	**7 p/km**
Capital costs of vehicle	Plus £5,000	

[52] *CH4-enriched biogas utilised as a transport fuel. Murphy J.D. Cork Institute of Technology.*

	CNG/Bio-methane HGV	Diesel HGV
Fuel Price	65 p / kg	113 p / Litre
Fuel Consumption	4 km / kg	10 mpg = 3.6 km / litre
Price per km	**16 p / km**	**31 p / km**
Capital costs of vehicle	Plus £25,000	

Information supplied by John Baldwin, CNG Services Ltd www.cngservices.co.uk

The procedures to become compliant with HMRC for paying Excise Duty is all laid out in 'Excise duty on gas for use as fuel in road vehicles HMRC Notice 76'. This can be found at: http://customs.hmrc.gov.uk/channelsPortalWebApp/channelsPortalWebApp.portal?_nfpb=true&_pageLabel=pageExcise_InfoGuides&propertyType=document&id=HMCE_CL_000173

The Biomethane Transport Forum which has a network of more detailed study than this project with regards to biomethane for road fuel is found at: www.environmental-protection.org.uk/transport/biomethane-transport-forum/. This is a useful site for converting and comparing calorific values of fuels http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html .

10. CONCLUSIONS

The UK's anaerobic digestion industry is still in its infancy but the opportunities ahead are considerable and policy is coming into place to make it a more lucrative and long term business for many entrepreneurs. This report has also highlighted the relevant barriers to overcome for individual businesses.

10.1. OPPORTUNITIES FOR THE INDUSTRY

These are multiple. The AD industry is growing swiftly as this report highlights. The number of parties interested in a project has doubled even since the first edition (22 months ago). Entrepreneurs see a profit in investing, environmentalists see the carbon saving, food supply chain companies see the waste disposal solution, policy makers see their targets being achieved and the local community benefits too. Not all the community sees it like this yet, but public awareness of the technology has already moved on greatly and will continue to do so in coming months.

Profitability

Whilst digesting animal slurry alone has been shown to work in UK conditions over a long period of time, under usual commercial conditions, it is not normally viable because low yields from slurry keep the revenue down.

Incorporating a home-grown or bought-in energy crop raises biogas yields considerably. It also introduces a major cost into the operation. If all the costs of producing and ensiling an energy crop are included (e.g. rent, overhead requirement and labour), then whilst the operation can become viable, new costs are incurred which depress profit.

Purchasing additional feedstocks is a simple way of considerably raising gas yield. Several examples are mentioned in the report including low value rolled wheat, sugar beet or glycerine. A steady and regular supply to augment the feedstock recipe blend should give a reliable and predictable gas yield and be straight forward to manage. An operator should know what the biogas value of each feedstock is and how much of a margin is being made at different price relationships.

The introduction of a third party waste stream as a feedstock opens the door to new overhead costs of meeting regulatory requirements, biosecurity measures and administrative procedures. However, this can offset the costs of energy crop production with revenues from gate fees and usually higher yielding feedstocks increasing returns from the biogas too. Management requirements increase considerably at this point, but this is how to maximise returns on capital from AD in the UK.

What is your Carbon Footprint?

The science of measuring a product's carbon footprint is moving fast. Supermarkets are encouraging suppliers to measure carbon consumption in their product manufacture (embedded carbon) and to identify ways to reduce it. The science and level of public perception is still in its infancy but is accelerating fast and a low carbon product will have increasing value to a supermarket in 2010 and beyond. Marks and Spencer, who in January 2007 announced a £200 million 5-year project (Plan A) to become a carbon-neutral business is seeking farmers to supply it with energy (not just electricity) from AD (http://plana.marksandspencer.com/). Tesco has announced it will be carbon neutral by 2050 and reduce its carbon footprint by 30% by 2020. It has recognised it is only one part of the supply chain and is encouraging its suppliers to participate.

A specification for the assessment of the life cycle greenhouse gas emissions of goods and services was launched in late 2008, the Publicly Available Specification (PAS) 2050. It specifies an agreed procedure for assessing the use of the gasses throughout the life time of a product.

The overall carbon balance of the AD and fuel power generation procedure is neutral, when taking the combustion of methane into account. However, if the AD feedstock is partially (or wholly) using what would otherwise be 'waste' streams that would end up in a landfill or incinerator, they could be considered as carbon positive, making a resource out of what would otherwise be an environmental burden.

As the UK becomes more accustomed to the concept of calculating an individual's impact on Climate Change through the emission of greenhouse gases, processes that can sequestrate carbon or remove carbon emissions from day to day business will probably become increasingly valuable. Currently, carbon trading has not reached farm level, but those businesses committed to reducing their carbon footprint will be likely to interact more with biogas plants, either as a feedstock supplier or by making use of the energy from the biogas.

The Rest of the Farm Business

The AD plant would almost certainly have several (mostly positive) interactions with the rest of the farm business. These include the supply of feedstock, provision of digestate offsetting fertiliser cost, use of labour in slack times of the farming year as well as a cheaper supply of electricity, heat and hot water not to mention eased cash flow and a useful way of mopping up other waste such as silage effluent. It is important to consider the relationship as symbiotically as possible. Each enterprise contributes to the whole farm margin and where they can assist each other is when the whole becomes greater than the sum of the parts.

Cooperation

On the subject of cooperation, it needn't be simply within a single farm business. The success of a biogas plant could be enhanced by the sharing of resources of two or more neighbouring farm businesses. For example, one might have more management time, another more land to produce energy crops and spread digestate. Not only would this provide the opportunity to enhance the capacity and therefore total size of the plant, but greatly raise the chances of attracting a grant from the Rural Development Fund (cooperation is very important in their allocation requirements).

Service to Society

The growth of the AD industry in the UK enables the land use sector to provide another highly useful service to local communities. It is a service that cannot be imported. Being geared up to take other people's wastes, treat them safely, and in an environmentally *advantageous* way (notwithstanding any food waste even if it is treated in an AD plant is still a waste of food) adds yet another string to the already well strung bow of what land based business actually does for society. In fact, it reflects the importance of land in virtually the entire renewables sector, many either benefiting from space (e.g. wind turbines), others fundamentally needing the products of agriculture to function (e.g. first generation biofuels).

10.2. Barriers to UK On-Farm AD

Whilst none of the barriers and obstacles that might be faced by AD developers should be underestimated, neither are they insurmountable. Every new venture, especially when the entire industry is young will present challenges to be overcome.

An Immature Industry

AD is an immature industry with the potential to develop and needs to address a number of issues:

- A lack of expertise in UK
- Undeveloped supply chain links (feedstock and digestate)
- difficulty using heat generated because of poor infrastructure

This is changing very fast and as the industry sees a future, so more expertise, technology, understanding about how AD works will develop to establish a mature sector. People looking to become involved in AD, either as an entrepreneur, investor or other, should select their partners carefully as there are a few self acclaimed experts in the field who have remarkably little experience or knowledge in the field. Beware.

Maximum Land Area

Land area is a limiting factor or obstacle to overcome in many situations. Some businesses have ideal conditions to host an AD plant but little land. In these situations, the cost of digestate transport is high and the digestate can become a liability rather than asset.

Biosecurity

Risks to animal health can become heightened from off-farm vehicular movements, particularly CAD centres. This is an area the UK is highly aware of, following foot and mouth disease in 2001 and 2007. Intensive (housed) livestock operations might find this a greater barrier but with the collection point away from livestock, this has been overcome throughout Europe and on farms in the UK.

The Corrosive nature of Hydrogen Sulphide

This is an issue clearly not exclusive to UK biogas operations. It has to be overcome everywhere. It does mean that some machinery will age more quickly and the plant machinery may rust more swiftly. However there are now several systems that include relatively effective hydrogen sulphide removal systems.

Losses from Digestate

Methane escapes from AD plants if the system is not entirely airtight. This is not only a problem for energy capture and therefore profitability, but also the environment. Methane can also escape from the system in feedstock and digestate storage before and after digestion respectively. Whilst methane losses from stored feedstock can be low, if care is not taken, aerobic decomposition (composting) will take place, eroding the potential energy within the organic matter that can be harnessed. This marginal loss can be dramatic as illustrated in the sensitivity chapter.

Business Longevity

The life of an AD plant should be in excess of 20 years. This timescale provides a far higher chance of a reasonable return on capital than say a five-year period. However, farm businesses cannot commit to keeping other enterprises that the AD operation depends on for that long. A farmer cannot be expected to keep a loss-making livestock enterprise going simply in order to feed the AD operation. Businesses must be flexible and responsive to changes in economics and circumstances.

Feed in Tariffs and Renewable Heat Incentives Policies and ROC Banding

We need to remember that at the time of writing, the FIT and RHI plans have not become policies and there remain hurdles ahead of their implementation. We trust their implementation will facilitate the growth of a vibrant industry.

Planning

Most people consider renewable energy and other environmentally positive enterprises to be a good thing. That is, as long as it's nowhere near them; here, the naivety of most people and resistance to changes (that affect them) becomes apparent at times of making planning requests. Good information and persistence with the planning stage appear to be the key tools for progress here.

10.3. FINALLY

Finally, it is clear that, as in any new major diversification enterprise, there is a considerable learning curve to climb and some big decisions to be taken. There are lots of people available to help, many with little knowledge or experience in AD, others with careful judgement and a track record, finding the right team to work with can in itself be tricky but is critical to get right. Taking the steps to become a biogas producer is a major change to most businesses which requires level headedness, conviction and commitment.

Good luck!

11. ANNEXES

11.1. GLOSSARY OF ACRONYMS

ABPR	....	Animal By-Product Regulations
AD	....	Anaerobic Digestion
BERR	....	Department for Business, Enterprise & Regulatory Reform
BSI	....	British Standards Institution
CAD	....	Centralised Anaerobic Digestion
CAP	....	Common Agricultural Policy
CCGT	....	Combined Cycle Gas Turbine (electricity generator)
CHP	....	Combined Heat and Power
CHPQA	....	Combined Heat and Power Quality Assurance
CNG	....	Compressed Natural Gas
COSHH	....	Control of Substances Hazardous to Health (1994 regulations)
DECC	....	Department of Energy and Climate Change
DEFRA	....	Department for the Environment, Food and Rural Affairs
DfT	....	Department for Transport
DTI	....	Department for Trade and Industry; now see BERR
EA	....	Environment Agency
ECA	....	Enhanced Capital Allowance
EP	....	Environmental Permit(ting)
ERDP	....	English Rural Development Programme
FIO	....	Faecal Indicator Organisms
FIT	....	Feed in Tariff
FYM	....	Farmyard Manure
GAP	....	Good Agricultural Practice
GHG	....	Green House Gas
HACCP	....	Hazard Analysis and Critical Control Points
HGCA	....	Home Grown Cereals Authority
HSE	....	Health and Safety Executive
kWh	....	Kilo Watt Hour
LATS	....	Landfill Allowance Trading Scheme
LEC	....	(Climate Change) Levy Exemption Certificate
LPG	....	Liquefied Petroleum Gas
MBT	....	Mechanical Biological Treatment
MSW	....	Municipal Solid Waste (garbage)
MW	....	Mega Watt
MWh	....	Mega Watt Hour
NERS	....	National Electricity Registration Scheme
NFU	....	National Farmers Union

NM^3 .... 'Normal' m^3. it refers to the volume of a gas at air pressure and 0^oc
NNFCC .... National Non-Food Crop Centre
NVZ .... Nitrate Vulnerable Zone
OFGEM .... Office of Gas and Electricity Markets
PAS 110 .... Publicly Available Specification 110
PAS 2050 .... Publicly Available Specification 2050
PPA .... Power Purchase Agreement
PPC .... Pollution Prevention Control
QP .... Quality Protocol
RAB .... Renewables Advisory Board
RDA .... Rural Development Agency
RDPE .... Rural Development Programme for England
REA .... Renewable Energy Association
REGO .... Renewable Energy Guarantee of Origin
RFA .... Renewable Fuels Agency
RHI .... Renewable Heat Incentive
RO .... Renewables Obligation
ROC .... Renewables Obligation Certificate
RPI .... Retail Price Index (inflation)
SP(S) .... Single Payment (Scheme)
TAC .... The Andersons Centre
TOE .... Tonne Oil Equivalent
VFA .... Volatile Fatty Acid
WML .... Waste Management Licence
WMR .... Waste Management Regulations
WRAP .... Waste and Resources Action Programme

11.2. GLOSSARY OF TERMS ~ JARGON BUSTER

Acetogenesis................................A process where anaerobic bacteria produce acetic acid from volatile fatty acids. The third phase of AD.

Acidogenesis ....A biological process converting simple monomers (such as amino acids) into volatile fatty acids.

Anaerobic ....'without oxygen'.

Biogas ....Gas formed from anaerobic digestion, being about 60% methane and 40% carbon dioxide, some hydrogen sulphide and ammonia.

Biomethane.................................Purified methane from biogas

Digestate ....The material left following anaerobic digestion.

Digester ....A tank in which the anaerobic digestion process takes place

Feedstock ....The material that feeds the digester (also ‘Substrate’)

Fibre ....The solid (dry matter) component of the digestate.

Horizontal Plug Flow ....A type of digester tank.

Hydrolysis ....The process of breaking down a compound by reaction with water.

Liquor ....The liquid (dirty water) component of the digestate.

Mesophilic ....A type of anaerobic digestion operating at 30 and 45^{o}C.

Methanogenesis ....Process where microbes (methanogens) form methane by binding hydrogen and carbon molecules.

Retention Period ....The time feedstock spends in the digester.

Substrate ....Another term of feedstock

Thermophilic ....A type of anaerobic digestion that operates at, or in excess of 50^{o}C.

Upgrading ....Purification of biogas into biomethane.

Vertical Tank ....A type of digester tank

11.3. ENERGY AND POWER DEFINITIONS

- 1 Kilowatt (kW) = 1,000 watts
- 1 Megawatt (MW) = 1,000 kW
- 1 Terrawatt (TW) = 1 million MW
- 1 kWe = 1 kW electrical power
- 1 kWt = 1 kW thermal (heat) power
- 1 therm of natural gas = 29.3 kWh t
- 1 kWh = 0.03413 therms = 3,413 BTUs (British Thermal Unit)

Power (watts) is the rate at which energy (Joules) is used.

A ‘tonne of oil equivalent’ (TOE) is equivalent to 11,630 kWh. So to convert from TOE to kWh, multiply by 11,630.

Table 33 ~ How many Household's Electricity can I provide?

MWh per year	Context
4.5	This is the overall average and is based on taking the total domestic electricity consumption in the UK and dividing it by the total number of households. The RPA believes this is the best number to use, but sometimes the number below is used.

3.7	This is the annual average for households connected to the gas network and that use gas for cooking and heating.
3.3	This is the figure currently accepted by Energywatch. It was also accepted by the Advertising Standards Authority in a recent rejection of a complaint about output claims.

Taken From Renewable Energy Association.

1 bar (about normal air pressure) = 14.5 pounds per square inch (PSI)

This is a useful site for converting and comparing calorific values of fuels http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html

11.4. REFERENCES, SIGNPOSTING AND USEFUL CONTACTS

Agencies Associations and Authorities

- England's Official Anaerobic Digestion Portal – www.biogas-info.co.uk
- Bayerische Landesanstalt fur Lanwirtschaft. Feedstock Yields www.lfl.bayern.de/ilb/technik/10225/index.php
- The Biomethane Transport Forum www.environmental-protection.org.uk/transport/biomethane-transport-forum/
- Lets Recycle site. A useful source of information http://www.letsrecycle.com/legislation/
- NNFCC Biocentre York Science Park, Innovation Way, Heslington, York, YO10 5DG Tel: 01904 435 182 www.nnfcc.co.uk
- OFGEM 9 Millbank, London, SW1P 3GE Tel: 020 7901 7000 www.ofgem.gov.uk
- The Environment Agency. www.environment-agency.gov.uk
- Quality Assurance for Combined Heat and Power. www.chpqa.com
- Renewable Energy Association REA 0207 747 1830 17 Waterloo Place, London, United Kingdom, SW1Y 4AR www.r-e-a.net/
- Anaerobic Digestion and Biogas Association http://www.adbiogas.co.uk phone 0844 292 0874
- Renewable Fuels Agency www.dft.gov.uk/rfa/
- Swedish Gas Centre. www.sgc.se/uk/index.asp
- Centre for Bio-energy (Denmark) http://web.sdu.dk/bio/

Biogas Providers and Support Companies Mentioned in the Report

- The Andersons Centre, Agricultural and Renewable Energy consultants: gredman@theandersonscentre.co.uk Old Bell House, 2 Nottingham Street, Melton Mowbray, Leicestershire, LE13 1NW 01664 503 200 www.theandersonscentre.co.uk
- Bekon Energy Technologies (Germany). www.bekon-energy.de/english/products.htm

- Organic Power www.organic-power.co.uk/
- Organic Waste Systems (OWS) Dranco. www.ows.be/pages/index.php?menu=89&choose_lang=EN
- Lundsby Bioenergi (Denmark). http://www.lundsby.dk/
- Schmack Biogas (Germany). www.schmack-biogas.com/wEnglisch/index.php
- Smartest Energy. www.smartestenergy.com/content/home.aspx. Tim Foster, Tel: 0207 448 0900 or tim-foster@smartestenergy.com
- The John Nix Farm Management Pocketbook www.thepocketbook.co.uk/ 01664 564 508

Policy Links

- **ABPR**

  Defra Front Page www.defra.gov.uk/foodfarm/byproducts/index.htm
- **Landfill Directive**

  DEFRA Front Page. www.defra.gov.uk/environment/waste/topics/landfill-dir/
- **Regional Animal Health Office** details www.defra.gov.uk/animalhealth/about-us/contact-us/animal-health-offices.htm
- **Environmental Permitting**: www.environment-agency.gov.uk/business/topics/permitting/default.aspx
- **Codes of Good Agricultural Practice**

  www.defra.gov.uk/foodfarm/landmanage/cogap/documents/cogap090202.pdf
- **Industrial Energy Crops**

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- **Planning Policy Statements** http://www.communities.gov.uk/planningandbuilding/planning/planningpolicyguidance/planningpolicystatements/planningpolicystatements/

Bills and White Papers

- Draft Climate Change Bill 2007 ~ www.official-documents.gov.uk/document/cm70/7040/7040.pdf

- Energy White Paper, Meeting the Energy Challenge 2007 ~ www.dti.gov.uk/energy/whitepaper/page39534.html
- Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of renewable energy sources: www.foeeurope.org/agrofuels/documents/Draft_RE_Directive.pdf

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11.5. Checklist for Anaerobic Digestion Investment

Overriding questions that need answering

Is AD right for the business and the farm system?

Do you want an AD enterprise on your farm or do you want to turn your farm into a waste management business on a farm? How fundamentally are you prepared to change your business?

Are the internal and external factors suited to AD?

What is the opportunity cost of AD on farm?

What are the added value opportunities of AD on farm?

What are the risks? How are they calculated?

Further added-value opportunities

Have you thought of…?

Layout ~ Purpose of Plant

- What's the feedstock?
- Maximising gas generation
- Maximising throughput
- Maximising fertiliser generation
- Waste/slurry digestion

Feedstock

- How much?
- All year, seasonal or intermittent? ~ Peak Load?
- Livestock housed or at grass?
- Feedstock blends
- Securing a favourable long term supply contract.
- Quality of feedstock
- Contaminants and wrapping

Planning Considerations

- Location
- Available space ~ Footprint
- Storage tanks
- Other resources e.g. manpower / capital
- Vehicular Movements
- Capacity, throughput and volume.

Type of AD Plant

- Mesophilic / Thermophilic
- Wet / Dry
- Single / Double / Multi-stage digester
- Vertical / Horizontal Digester
- Plug / Flow
- Batch / Continuous

Environmental

- Smell
- Gas Emission Guidance
- Digestate
- Lorry movements
- Gas generation
- Leakage

- Bunding

Permits and Authorisations

- ABPR
- EP
- ROCs
- LECs
- Digestate Certification quality protocol
- Quality assurance protocols from feedstock suppliers
- Planning Permission
- CHPQA
- Health and Safety
- Testing the digestate
- Gas engine manufacturer's warranties
- Feed In Tariffs
- Renewable Heat Incentives

Business Planning ~ Sales and Marketing

Electricity

- To 'the grid': Contract terms, short/long
- To a neighbouring user
- Solely on farm and farm house

Selling Digestate

- Quality assurance
- Volume
- Sufficient land area/customers
- Dry or wet

Intake

- Slurry
- Others' slurry
- Energy crops
- Non-farm waste e.g. glycerol
- Economics ~ Income
- Gate fees
- Fertiliser/digestate
- Biogas
- Electricity

Business Impacts

- Effect on other enterprises on the business such as rotation if crops required as feedstock
- Longevity of other enterprises that plant relies on?
- Demands on current resources including:
  - Demand on capital, is the bank supportive?
  - Demand on key staff
  - Balance of total business risk; financial exposure, debt levels,
- Ensure the AD enterprise is not simply being built to subsidise a series of currently loss making enterprises, each enterprise should be profitable in their own rights.

Set-up Capital Investment

- Opportunity cost of resources
- Feedstock reception area
- Feedstock blending tanks
- Feedstock storage tanks
- Feedstock shredder/pulveriser/masher
- Digester
- Monitor and control system
- Odour retention system
- Boiler to warm digester
- Biogas condenser
- Biogas scrubber (H_2S)
- Biogas on-line filters
- Heat exchanger
- Necessary piping and connections
- Electricity Generator
- National Grid connection and meter
- 3-phase electricity connection?
- Digestate Storage Containers
- Biogas storage
- Gas handling facilities and flare stack
- Loading facility
- Dewatering, such as a weeping wall or sieve separator
- Necessary pipes, vales and other connections
- Laboratory?
- Administration office?
- Weighbridge? Volume recording meters

Income

- Maximising revenues
- Keeping plant operating at full capacity
- Ensuring the correct blend of feedstocks
- Correct moisture levels
- Making use of heat?

Operating Costs

- Transport
- Energy
- Other utilities
- Insurances
- Labour
- Maintenance
- Administration

Grant Funding

- RDA
- Enhanced Capital Allowances
- Bioenergy Capital Grant Scheme
- National Grant Schemes
- Other Local funding

Solving Problems

- Irregular gas supply/fuel requirement
- Nitrates Directive

- Competition?

Opportunities on a wider (National) Scale

- Energy Security
- Landfill reduction
- Carbon neutral/positive
- GHG reduction
- Green credentials

Benefits

- Carbon neutral or carbon positive
- Wastewater treatment
- Digestate management / sale
- Biogas utilisation