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GROUP

*A Review of
Anaerobic Digestion
Plants on UK Farms*





Supporting Sustainable Agriculture

**A Review of
Anaerobic Digestion Plants
on UK Farms - Barriers, Benefits
and Case Studies**

Angela Bywater

Report prepared with financial support from
the Frank Parkinson Agricultural Trust

About the Author

Angela Bywater has a background in IT, having implemented and managed projects for a number of well-known UK companies, including House of Fraser and Sun Life of Canada. An interest in anaerobic digestion (AD) was sparked when she was asked to project-manage the construction of a digester and other building works in early 2001. Over the last decade, she has maintained an interest in the technology and has been involved in a number of AD-related projects and publications. An avid gardener with an interest in sustainability, she is currently focussing on small farm and micro-AD technologies.

Royal Agricultural Society of England

Since 1840, the Royal Agricultural Society of England has played a leading role in the development of agriculture, the food chain it serves and the rural economy within which it operates. As the independent voice for the sector, the Society encourages innovation, the advancement of science, and effective knowledge exchange.

A thriving agricultural industry relies upon the rapid uptake of scientific advance. The Society is committed to improving the profitability and competitiveness of rural businesses by providing a link between research and production.

“Practice with Science” is the Society’s motto and still represents its core purpose today. The “Practice with Science” Advisory Group, chaired by Professor David Leaver, is tasked with identifying issues of strategic importance to agriculture, and advising the RASE Executive and Trustees accordingly.

The “Practice with Science” Group commissioned the report “A Review of Anaerobic Digestion Plants on UK Farms” in order to understand why there was not a greater take-up of AD on farms in the UK. The Society also wanted to hear directly from farmers who have installed anaerobic digestion plants.

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Frank Parkinson Agricultural Trust

The Frank Parkinson Agricultural Trust was founded in 1943 by the engineer and entrepreneur Frank Parkinson, who died in 1946. The aim of the Trust is the improvement of British agriculture. For almost seventy years, the Trust has provided funding for education and research in British farming. The Trustees are delighted to support the report by the Royal Agricultural Society of England on anaerobic digestion on UK farms.

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Barriers, Benefits and Case Studies

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Executive Summary

Between 90 and 100 million tonnes of slurry are produced on UK farms (plus other solid manure from beef and poultry farms), with attendant odour and greenhouse gas (GHG) emission problems¹, as well as potential for run-off which pollutes watercourses.

This report makes extensive use of case studies to explore best practice in a number of anaerobic digestion (AD) plants, each unique in their own way, as well as looking at barriers to AD and the benefits identified by the people who are actually running plants at a farm scale.

All of the farmers involved in the case studies lauded the numerous benefits of AD which included:

- improved slurry handling;
- the ability to target crop nutrients;
- increased nutrient uptake;
- increased spreading windows;
- less crop taint and decreased re-grazing times;
- significant odour reduction when compared with slurries ;
- a reduced/nil reliance on fossil based fertilisers;
- reduced reliance on fossil fuel-derived heat;
- a vastly decreased potential for watercourse pollution;
- fewer emissions to air (odour, ammonia and GHGs);
- environmentally friendly farm diversification.

“The benefits of AD to sustainable farming are numerous, but not one on its own is sufficient to justify installation”

-Murcott

In other words, on-farm anaerobic digestion offers a significant step towards more sustainable farming. It is for these reasons that the UK Government and the agriculture industry see anaerobic digestion as the ideal way to treat slurry. As stated in DEFRA’s Shared Vision for Anaerobic Digestion, the NFU would like to see 1000 on-farm digesters by 2020. Work done by the RASE and AEA Group² indicates that for the greatest impact, low-cost AD plant should be targeted at dairy farms, starting from about 100 cows and upwards.

¹ Including reduced nitrogen NH_x (e.g. ammonia, ammonium), NO_x, methane and carbon dioxide.

² Bringing small scale AD to UK farmers – the challenge; Paper presented by Prab Mistry (AEA Group) & Ian Smith (RASE) at the European Bioenergy Expo and Conference; Stoneleigh Park, Warwickshire, UK; 6 - 7th October, 2010.

If UK farmers are to change the way they handle slurry, the primary incentive that is currently available is the Feed-In Tariff (FIT), based on the installation of an AD plant. The FIT, administered by DECC³, does *not* encourage farmers to reduce pollution, but rather pays them to generate renewable electricity using a combined heat and power plant (CHP) which runs off biogas from the AD process.

However, combining AD with CHP to create electricity currently has a number of appreciable difficulties if compared with direct gas use (e.g. in a boiler). These include grid connection issues, significant extra capital/maintenance costs and plant complexity in terms of engineering a system which can continuously produce sufficient quantities of quality gas.

The average farmer's options to fully and economically utilise their slurries in an environmentally friendly manner are further compromised by the fact that:

- the primary feedstock (cattle slurry) is generally only available for 6 – 7 months when cows are housed indoors over the winter months;
- sufficient year-round on-farm organic substrates⁴ may be limited;
- there are significant regulatory financial penalties imposed for digesting the off-farm substrates (which have to be returned to land, anyway), including those which can be fed to cows.

Some farmers may not have the option or desire to grow energy crops in order to boost biogas output to improve the economics of using AD with CHP, for what is primarily their slurry treatment system, especially if the cost of bought in feed increases in line with fossil fuel costs, putting further pressure on farmers to grow their own crops to feed their cattle.

A further barrier is access to capital. Pollution control and other capital grants have largely been phased out. Banks are not prepared to lend money for a technology with which they are largely unfamiliar and suspicious of. In addition, the UK AD market has been slow to develop (compared to elsewhere in the EU), so technology suppliers of smaller plant, where margins are smaller, tend not to have a large working capital base themselves, further increasing investment wariness.

The case studies illustrate that, for many of the average sized farms in the UK, direct use of the biogas⁵ from the AD slurry treatment system might be a simpler and more cost effective option. This is because of the seasonal availability of much of the primary feedstock (slurry) and the cost, complexity and connection issues surrounding the use of CHP with AD.

However, the only incentive that direct gas use is likely to attract is the Renewable Heat Incentive (RHI), which is unlikely to provide sufficient income to make it economic for many

³ Department of Energy and Climate Change – the Government Department which brings together energy policy and climate change policy.

⁴ A substrate is simply an organic feedstock which is fed into a digester

⁵ The biogas is used in boilers, Agas, Rayburns or similar to heat the house, hot water, dairy, dairy washings and other buildings as needed.

of these farmers to install AD. On smaller digesters, a relatively larger proportion of the biogas is used for digester heating and this use is unlikely to attract the RHI.

It is clear that few farmers have the resources or desire to invest in large scale AD plants and would prefer a solution that was more appropriate to the needs and capability of their farming operations. There is clearly a demand for small scale farm based digestion.

Farm slurries can, with the appropriate technology, be digested in smaller scale AD plants on farms with other feedstocks that are available locally and can be included without excessive additional regulation. There is a perception that only large scale AD plants are viable, but the case studies and discussion with industry players show that this need not be the case. There are a number of factors that must be taken into account if farm scale AD is to take off:

- smaller AD projects which have the additional environmental benefit of treating ‘the slurry problem’ need a new, preferably incremental and unconditional⁶ FIT band with a higher rate to boost viability on AD with CHP, as well as sufficient Renewable Heat Incentive for direct gas use where CHP is not an option. The incentives for AD should make it at least as attractive as simply putting up a slurry storage tank which still has slurry handling, pollution and GHG emission problems;
- access to capital grants or rolling loans with preferential terms (for example, along the lines of student loans) need to be considered, possibly partly or wholly funded by relevant organisations (such as supermarkets) wishing to reduce the carbon footprint of their supply chain and who enjoy the cost benefits of farms which reduce GHG pollution as well as reliance on fossil fuels and fertiliser;
- access to a wide range of off-farm local organic feedstocks. Light touch regulatory controls on low-risk organic substrates, as well as regulatory flexibility to allow for organics which may have undergone pre-processing⁷ to be used as an AD feedstock on farm;
- a desire by farmers for AD technology that is simple, robust and cheaper to install. Small scale modular plants, similar to a number of those illustrated in the case studies, will help reduce costs.

The case studies also illustrate that a combination of barriers are limiting the uptake of AD.

However, if the Government and the regulators wish to employ the immense potential of AD to reduce GHG pollution from organic substrates and efficiently return nutrients back to the land whilst creating renewable biogas and reducing the carbon footprint of agriculture, it is

⁶ ‘Unconditional FIT’: access to the FIT will not be conditional on the type of feedstock put into the slurry based digester, as the volume and quantity of feedstock is limited by the digestate nutrient application rate on the available landbase. ‘Incremental FIT’ works like income tax, where all are paid the higher rate for the first 50kW, then access the lower rate if they go over. This saves trying to limit a biological process to 49.9kW in order to obtain the higher rate, where it may be more sensible to run 55kW.

⁷ Pre-processing in terms of a number of treatments which may involve de-packaging, pasteurisation, autoclaving, sorting, etc, at a central facility: a ‘hub and point-of-digestion’ model.

necessary to ask if the current drivers and incentives for the technology are sufficient and appropriate to ensure the uptake of the technology at the scale where it is most needed. In order to be appropriate to the drivers for on-farm AD, in due course, the incentive system should be adjusted to be based on the net carbon reduction that is achieved, although it may still be necessary for some banding to promote smaller scale rural projects.

The UK has the expertise to continue to develop the technology for smaller scale AD applications and this would be helped further by a framework which ensures that this is a viable proposition.

Foreword

Anaerobic digestion (AD) is a process that has been used very successfully in a large number of countries, developed and developing, over many years for a number of purposes including energy production, nutrient management, waste stabilisation, and pathogen reduction. In all of these uses, it also contributes towards reducing greenhouse gas emissions, both directly and by offset.

It is the only technology currently in the market place that meets the European criteria for second generation biofuel production, and can achieve this using a range of mixed wastes, not just purpose-grown biomass. It is also a technology that has been neglected by successive governments which have climbed on the bandwagons of hydrogen, ethanol and biodiesel as the renewable biofuels of the future, despite the fact that biogas plants using the same substrates give consistently higher net energy yields.

Even now that the UK Government has embraced AD as a key technology, it still seems uncertain in which role to deploy it! If left to market forces, AD will certainly make money for those who invest in large centralised processing plants that accept high energy-value waste inputs, charge gate fees, and receive subsidy for the heat or power they produce.

This is not, however, a solution that will maximise the energy potential of the available waste biomass, as by far the largest tonnages of materials are animal slurries and manures produced on farms. Although the energy potential of these per tonne is low, if they can be digested on farms, the overall net energy yield is significant.

An even greater benefit may be the fact that digestion can reduce greenhouse gas emissions associated with manure management and improve nutrient management on the farm. But, as this report clearly shows, digestion of this biomass resource on its own is not economic. If it were, then market forces would already be operating and digesters on dairy farms and intensive livestock rearing units would be commonplace.

Where farm-scale digestion is successful in Europe, this has been as a result of subsidies for the energy produced and guaranteed long-term markets for it, allowing investment to be made on a sound business plan. This has certainly resulted in an exceptional growth in farm digesters with, for example, more than 4000 plants in Germany, generating more than 1 GW of electricity and, in some cases, also making use of surplus heat. The success of these schemes, however, has been based on production or import onto the farm of energy crops such as maize, and not on the digestion of manure or slurry alone, although this may form part of the mix.

Such schemes raise the question of what should we be using our land for – food or fuel? In a world where the population is projected to reach over 8 billion within the next generation, it is clear that the demand for food will continue to rise and the use of agricultural land for the production of biofuel or electricity may be unacceptable.

The question also arises, why is it necessary to grow biomass specifically for energy production when about half of the biomass grown for food production ends up as waste in the field, at the processing plant, or arising from homes and commercial premises? The first priority must be to gain the maximum benefit from this waste, and that may not mean simply cherry-picking those wastes with high energy value for separate digestion, but considering a

more holistic approach that aims to maximise the environmental and farming benefits which can be achieved using the digestion process.

As highlighted in the report, the current system of reward via a feed-in tariff system is not the answer: in Austria and Germany, this has led to the production of energy crops, and although UK farmers have so far resisted this concept, the decline of the dairy industry may force them down this route. More imaginative thinking is required on the part of Government and its policy advisers to put into place a regulatory regime and drivers that allow farmers in the UK to build and operate slurry digesters in order to reduce GHG emissions from dairy and other livestock farms, improve farm hygiene, reduce the risks of nutrient leaching, improve farm income, and stimulate the rural economy.

The report puts forward arguments for changes in current thinking and to the drivers already in place, and goes a step further in presenting a sound scientific base as to why these changes are necessary and the benefits that can be gained from them.

These arguments are supported by the views of farmers who own and operate digesters. Here, attention turns to the positive farming benefits that can be gained from digesting slurry, such as easier spreading, reduced odour, less tainted crops, fewer weeds, lengthened spreading window and others. These positive benefits are now outweighed simply by the cost of the digester, which has escalated due to the difficulties in gaining both the necessary permissions and the finance to start an on-farm digestion project.

Regulation is an essential part of ensuring environmental protection, but digestion plants are still viewed with suspicion by regulators and planners, compared to composting plant where there is a standard permit for small-scale operations of less than 500 tonnes on site, which allows the import of a wide range of organic wastes and is suitable for on-farm composting.

The standard permitting for digestion applies to plants of up to 75,000 tonnes per year and there is a requirement for extensive controls that are not relevant to farm-scale operation. There is thus an urgent need for a standard permit for small-scale digestion; a need to simplify the planning process; and a need to make the financing of on-farm digester projects more attractive. It is important that the uptake of farm digestion is encouraged in order effectively to utilise the organic resource that we call 'waste'.

The animal slurry alone has a methane potential of around 1 billion m³ or 10 billion kWh of energy per year: looking at this in another way, if this material is not digested, then the estimated GHG potential is 3 Mtonnes CO₂ equivalent based on DECC 2009 greenhouse gas emissions data. So it is time to be innovative, proactive and helpful in promoting a technology that brings multiple benefits with very low risks.

Professor Charles Banks
University of Southampton

1 Introduction

One of the aims of the Royal Agricultural Society of England (RASE) is to employ science to help inform agriculture and to help agricultural practices evolve. Indeed, the Society's motto is "Practice with Science". RASE commissioned this report because, with the influx of European technology into the UK, it felt there was a danger of a 'one size fits all' approach to anaerobic digestion. There is also concern that policymakers and regulators are focused on large sized AD plants and that this is distorting the industry in the UK.

The UK experience shows that farmers are not only happy to have an AD slurry treatment system on their farm, but that several early pioneers have even built a second. It also appeared that there had been little investigation as to why this technology was actually working for some farmers (albeit in modest numbers here in the UK) and little, if any, compilation of their opinions on the technology or what practitioners consider makes AD work (or not) at a smaller scale.

So what is meant by 'small-scale', especially in the context of UK farming? Undoubtedly, much can be learned from the European experience, particularly the Danes and Germans, whose AD industry has had solid governmental support for decades. However, UK farming is different in a number of ways, including the average type and size of farms, farming practice and environmental incentives.

DEFRA's 'Anaerobic Digestion – Shared Goals' document states that the 'NFU vision for Anaerobic Digestion sets an aspiration of 1,000 farm-based anaerobic digestion plants by 2020'. With a current estimated number of only about 50 farm-based AD plants in the UK, the challenge of 1,000 AD plants by 2020 does seem daunting. In order to achieve this, we would need to build approximately 8 plants per month, every month, until 2020. That is indeed a challenging target and it still only takes in a small proportion of the farms in the UK⁸ which might conceivably adopt AD technology.

To highlight the benefits of AD to the farming community, it is necessary to target the types of farm where AD will have the greatest effect, reducing the environmental impact of farm pollution and in ensuring that the plant is cost-effective for the farmer. To address this, the RASE has partnered with the widely respected AEA Group⁹ to provide the technical, economic and commercial basis for targeting a 'real on-farm' AD concept; i.e. where biodegradable materials sourced from within the confines of the farm are digested. This analysis has provided the basis for this report.

To define the case for the economic viability of on-farm AD, AEA used a detailed database of information on UK farms to identify the types of farms on which AD would be most cost-effective. AEA's model considered the current economics of on-farm digesters and their sensitivity with respect to other parameters related to farm management practices; this analysis is given in Appendix A – The Low Cost AD Challenge.

⁸ www.ukagriculture.com – approximately 300,000 holdings, of which 200,000 have slurries.

⁹ AEA has a track record of devising innovative approaches to Government programmes, policy development and strategy formulation.

Having identified where AD is likely to have a reasonable Internal Rate of Return (IRR), the question arises as to what is to be gained through implementing AD as a technology on farms? The scope for potential reduction in carbon footprint is considerable. By volume, there is 4.5 times as much farm derived organic material (manures and slurries) as from food: 90 million tonnes as opposed to 20 million.¹⁰ Human sewage sludge, which is generally very dilute, amounts to less than 2 million tonnes on a dry weight basis or between 25%-50% when compared on a dry weight basis with slurries.

As a society, we are happy to pay to minimise the environmental impact and health issues associated with the treatment of 'humanure', yet farms, especially smaller ones, have very little incentive to deal with a problem which is much greater. When properly implemented as part of a slurry management system, AD is critical to reducing both greenhouse gas emissions and watercourse pollution from slurry run-off.

Additionally, our food comes from the land and it is vitally important that we return nutrients to the land, ideally in a readily available form. AD is the ideal technology to do this in the form of digestate. Finally, in the past 100 years, our food production has become increasingly reliant on fossil fuels and this leaves our farming businesses highly vulnerable to rising prices of fossil-based fertilisers, fuel and electricity. AD can help reduce this reliance.

But if AD is indeed such a wonderful technology for treating organic substrates, why has it not been more widely accepted in the UK and particularly on UK farms? Conversely, why are those who have used the technology so passionate about its benefits? These early adopters are key stakeholders and sterling ambassadors for successful farm-based implementation of the technology throughout the UK. They know the benefits, they know the problems, they know the barriers to the technology and yet their voices are so seldom heard.

Thus, this report is firmly anchored in acquired knowledge and experience, demonstrated through case studies. The case studies illustrate how farmers have used the technology successfully, here in the UK, often over decades. They illustrate various types of digesters, how the technology has integrated into widely different farming practices and what farmers believe to be the benefits and barriers. The experienced voices of the farmers come through. (These are recorded in detail at Appendix B – Case Studies.)

RASE is grateful to them for their cooperation, for explaining their systems with their attendant benefits and challenges. A number of digester suppliers and consultants have kindly provided their insights in this area, particularly with regard to technical information and some of the generic barriers faced by the technology.

The author has sought to minimise the use of the word 'waste'. An organic waste is merely an organic resource that is being handled inappropriately. However, the Environment Agency has a very specific definition of what constitutes a waste and adopters of the technology need to ensure they comply with these regulations.¹¹ A detailed discussion of

¹⁰ AD Shared Goals, February 2009, available from <http://www.defra.gov.uk/environment/waste/ad/documents/ad-sharedgoals-090217.pdf>

¹¹ www.environment-agency.gov.uk/.../PS_029_AD_of_agricultural_manures_and_slurry_final.pdf

the regulations is outside the scope of this report, although farmer experience of them has been referred to in the conclusions.

It is apparent from the case studies that successful implementation of anaerobic digestion on farms involves three things: an understanding of farming practices, an understanding of anaerobic digestion and an understanding of how to engineer a robust, feedstock-tolerant and farmer-friendly system. If set against the background of supportive incentives for pollution control, carbon footprint reduction and sensible regulation, the UK could go a long way to creating a flourishing AD industry and achieving its environmental targets.

A M Bywater
March 2011

2 What is Anaerobic Digestion?

The Environment Agency¹² defines anaerobic digestion (AD) as “mesophilic and thermophilic biological decomposition and stabilisation of biodegradable waste which:

- (a) is carried out under controlled anaerobic conditions; and
- (b) results in stable sanitised material that can be applied to land for the benefit of agriculture or to improve the soil structure or nutrients in land.”

The decomposition process is carried out by micro-organisms in controlled conditions in the absence of oxygen. It creates biogas and digestate which can be used as a fertiliser and soil conditioner.

Biogas typically consists of 50-75% methane, with much of the remainder being carbon dioxide. Small volumes of nitrogen, hydrogen, hydrogen sulphide and oxygen are also found in the biogas. The biogas can be used directly by burning it in a boiler, Rayburn or Aga in order to heat buildings and water for domestic or farm use. It can also be used to run a Combined Heat and Power plant (CHP) which has the additional benefit of creating renewable electricity.

Digestate can be put on crops and is valuable in recycling nutrients back to land. Where appropriate, this digestate can also be separated into a fibre and a liquid fraction. The fibre can be used as a soil conditioner. Since the liquid fraction contains the bulk of the nitrogen, separation gives farmers more flexibility to target nutrients as needed.

Digesters can be characterised by the temperature at which they operate. ‘Mesophilic’ digesters are by far the most common and operate at temperatures between 20°C and 45°C, but typically around 30-38°C, although several of the digesters in the case study operate in the 38°C-40°C range. All the digesters studied in this report are mesophilic.

This process of biomass decay involves a distinct series of reactions where the metabolic products of each stage act as food for the bacteria in the next stage. The stages are hydrolysis, acidogenesis, acetogenesis and methanogenesis. ‘Methanogens’ belong to a special group of single-cell micro-organisms called archaea, but for the layman, the AD process is generally seen as being carried out by ‘anaerobic bacteria’. Much like running a car, it is not necessary to know what goes on ‘under the bonnet’ of a digester in terms of the biochemistry, but many potential owners or operators will find it useful.

Theoretically, if all the water were removed from the feedstock, only dry matter (DM) would remain. Of this dry matter, only a proportion has the potential to produce energy and this is known as the organic dry matter (ODM). The composition of the feedstock in terms of carbohydrates, fats and proteins will determine the biogas yield.¹³

¹² http://www.environment-agency.gov.uk/static/documents/Business/Glossary_of_terms_-_waste_exemptions.pdf

¹³ European Energy Manager Biogas Preparation Material

Because of the varying biogas potential of different feedstocks in this biological process, it is important to ascertain the types and quantities of feedstock¹⁴ going into the digester. Fats tend to have a very high potential biogas yield; slurries a much lower potential, as the animal has already extracted much of the energy from the original food.

Based on quantity and type of feedstock, digester suppliers will use 'typical' values when determining plant size and biogas potential, although this can vary between supplier and the actual feedstock fed into the digester. For example, if stored slurries suffer from rainwater ingress, the actual biogas potential may vary considerably from the theoretical values. An AD calculator which includes typical biogas values and other useful information can be downloaded from the AD Portal¹⁵.

An anaerobic digester can potentially digest any non-woody organic feedstock, including slurries/manures, as well as surplus or unneeded organic materials from crop production, food processing and household/supermarket/restaurant food use.

¹⁴ Also known as a substrate

¹⁵ www.biogas-info.co.uk

3 History of on-farm AD in the UK

Biogas may have been used for hundreds or possibly thousands of years by Assyrians, Persians and the Chinese. In the UK, biogas from a sewage treatment facility was used to fuel lamps in the city of Exeter as early as 1895¹⁶ and by 1922, a Birmingham sewage works had an engine running on sewage gas.¹⁷

With fuel shortages during the Second World War, methane gas was used to run vehicles, particularly in Germany and France. After the war, countries such as the UK, Canada, USA and Russia showed an interest in AD but, due to the low prices of fossil-fuels, interest in the technology waned.¹⁸ However, the energy crisis of 1973 resulted in a revival of interest in alternative renewable energy technologies.

Seminal writers of this time include South African L John Fry and Peter-John Maynell, author of Methane: Planning a Digester. Also, around this time, Peter N Hobson did a lot of work on AD at the Rowett Institute in Scotland, particularly by trying to reduce odours from pig slurry.

It can be seen from the literature that the energy crisis precipitated the birth of what was to become the AD industry in countries such as Germany and Denmark. In the UK, it was largely because of this crisis that young engineer James Murcott became interested in anaerobic digestion and began to build a small fibreglass digester.

Seeing a bag-style digester at the 1974 RASE Muck event at Stoneleigh Park reinforced his opinion that AD was the perfect technology to treat slurry, recycle nutrients back to land and generate energy.¹⁹ When Michael Chesshire joined him in 1975, the company Farmgas was born, exhibiting a fully working digester at Stoneleigh for Muck '77.

Over the next 14 years, Murcott and Chesshire created the UK's largest anaerobic digestion plant manufacturer of the time, building sewage works digesters, as well as around 16 units on farms. It was around this time that an environmentally aware Welsh farmer, Wyn Evans, built his own digester, having had two original small Farmgas digesters (see Case Studies, page 58).

When Farmgas decided to stop manufacturing farm digesters in 1989, Murcott joined forces with Jon Letcher and formed Waste Refineries International (WRI), building a similar number of farm digesters in the years 1990-1995, including the 1994 digester at Walford College.

Michael Chesshire went on to form Greenfinch (now Biogen Greenfinch) and built a number of digesters, including 7 Scottish Executive funded digesters in southwest Scotland, as well as the well-known food waste digester at Ludlow. At one time or another over the 20 year period between 1975-95, it is estimated that around 40 smaller companies each built one or

¹⁶ Wikipedia & <http://www.kingdombio.com/history1.html>

¹⁷ <http://uk.reuters.com/article/idUKTRE68R4EE20100928>

¹⁸ Biogas Systems : Policies, Progress And Prospects By K. M. Mital.

¹⁹ New Scientist, 4 Mar 76

a few on-farm digesters in the UK, but not many of these digesters are still in operation today.

The largest number of UK on-farm digesters were built between 1987 and 1995 under the Government's pollution abatement grant scheme. These were typically 50% grant aided to enable farmers who applied and met the relevant criteria. Although it encouraged the building of a number of AD plants, its aim was to enable farmers to reduce pollution by managing their slurry more effectively. When compared with other slurry management solutions such as weeping walls, anaerobic digestion proved to be a cost-effective alternative, albeit relatively unknown to the UK farming community. For much of this period, planning permission was not needed and there were no regulatory requirements other than to reduce pollution from slurry runoff.

With the withdrawal of the pollution abatement incentive in 1995, the farm-scale AD business found itself in the doldrums for the next decade. After 1995, Government initiatives like the NFFO electricity incentives were designed to encourage Centralised AD (CAD) plants, along the lines of the Danish model. The standard Danish CAD plants co-digest approximately 70% animal slurries with a maximum of 30% biodegradable wastes from commercial and industrial (C&I) premises.

The only plant built in the UK under the NFFO incentive was the Holsworthy plant in Devon, an area notable for its high concentration of dairy farms. The plant was built by the German firm Farmatic and completed at the end of 2002, and was designed to primarily take slurry from more than 25 dairy farms within an 8 km radius, as well as pig slurry, poultry manure and a relatively small proportion of food waste (20%), producing a maximum of 2.1MW electricity.

The £7.85 M plant was 50% grant funded, which included a £3.85M European Union grant.²⁰ The Holsworthy model proved to be uneconomic and the plant has now changed ownership. It no longer takes any farm substrates, although digestate from the plant is spread onto local farm land.

At the other end of the scale, Clive Pugh, who had installed the first WRI digester in 1990 and was a passionate advocate of anaerobic digestion, enlisted the help of James Murcott to build a second anaerobic digester on his Welsh farm, plus a covered slurry store (details are included in the Case Studies: Clive Pugh – Bank Farm). This project was co-funded by a Welsh Farm Diversification Grant.

Recent years have seen a cautious resurgence in interest in farm scale anaerobic digestion, with a number of European suppliers making moves into the UK market. This interest has been sparked by the UK government offering double-ROCs²¹ and, more recently, renewable energy Feed-In Tariffs (FITs), as well as the Renewable Heat Incentive (RHI) which was

²⁰ http://www.devon.gov.uk/renewable_energy_guide_case_study_2.pdf

²¹ Renewable Obligation Certificates – incentives for renewable electricity production

announced in March 2011²². None of these incentives were designed with AD specifically in mind, but apply to a range of renewable energy technologies.

Notable among the larger scale on-farm AD systems that have been installed in recent years is William Luttmann-Johnson's £2.5M farm digester, which produces 1MW of electricity from 700 dairy cows, maize silage grown on the farm and other bought-in crops. This was the first farm digester of this size using only agricultural substrates in the UK.²³

On a smaller scale, a number of other farm digesters have been built recently, including Kemble Farms (page 43), the Greenfinch-built Scottish digesters (page 87), Bedfordia's Twinwood digester, Owen Yeatman's Biogas Nord Dorset plant, Gask Farm's Weltec plant in Aberdeenshire, Lodge Farm's Fre-Energy plant in Wrexham (page 64) and a growing number of others.

²²

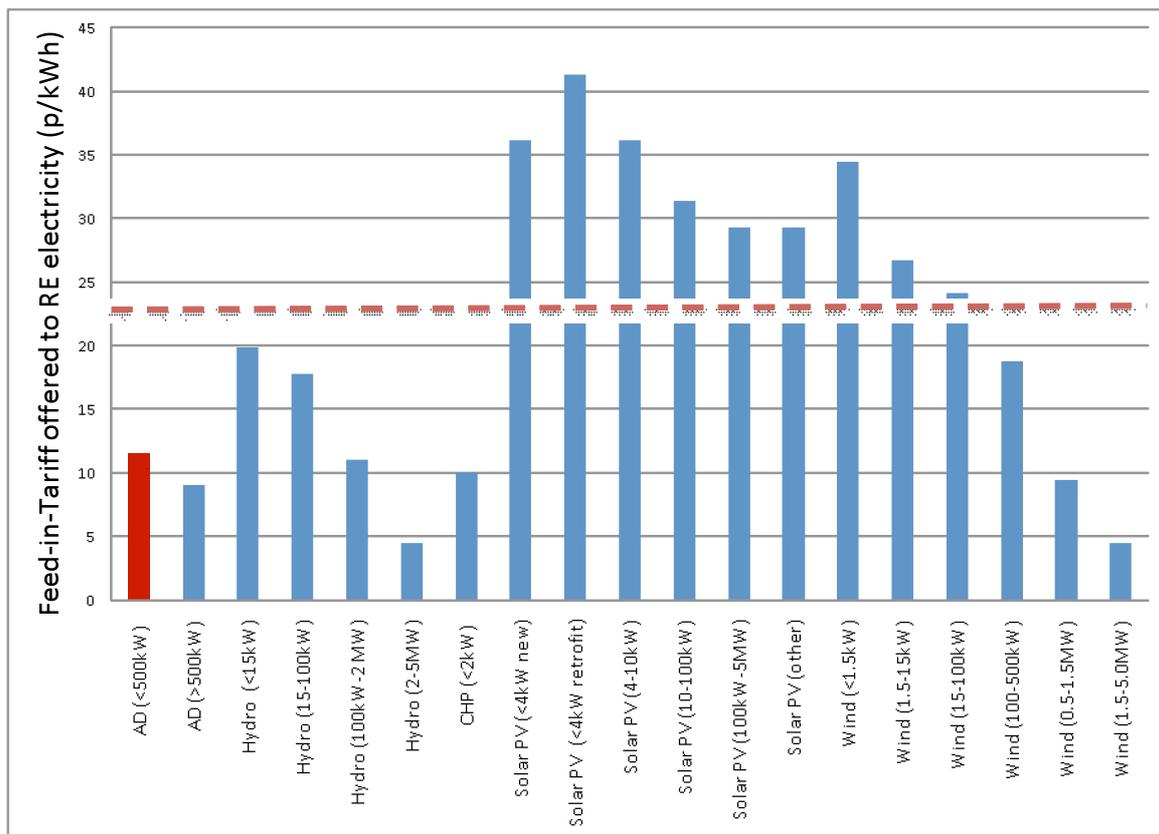
http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/incentive/incentive.aspx

²³ http://www.atlasfram.co.uk/Attachments/Resources/350_S4.pdf

4 The Small-Scale AD Challenge for Farming

There was considerable disappointment in the UK AD industry when the Feed-In Tariffs (FITs) Scheme was announced in April 2010, due to the low levels of the FITs (and lack of banding) for 'small-scale' AD, especially when compared with incentives such as those for small-scale Solar PV.

The introduction of FITs for PV (photovoltaic cells) could easily create a reasonable rate of return for installations as small as those on a single house, but FITs for AD were generally not considered attractive enough to create a reasonable rate of return on the majority of small farms. A comparison of incentives for the varying technologies is shown below:



Whilst it is acknowledged that the adoption of on-farm AD should be encouraged in the UK, more needs to be done to encourage development of smaller farm-scale AD systems suited to UK market requirements that would enable British farmers to install appropriate systems. For instance, for a farm having approximately 150 dairy cattle, it would be appropriate to offer double the FIT rate (shown as red dashed line in the figure above) or capital grant until the technology was established. This will go a long way to making AD the first choice in managing slurry at such livestock farms. Economic and financial viability of AD plant is determined by three main factors:

- Capital cost;
- The level of the feed-in tariff for electricity sale;
- The proportion of the year that stock are housed.

The RASE, working with other partners, including the AEA, WRAP and the NNFCC, has been exploring ways in which it might help to stimulate the development of small scale on-farm AD technology and the uptake of AD for treatment of farm slurry and locally available feedstocks in the UK.

There is a variety of on-farm digesters in the UK, incorporating a considerable number of innovative ideas. Some of these digesters are uncomplicated and in line with the kind of 'simple to operate' requirements needed for wide-scale application of this technology on farms. In order to bring the farming community, as well as the developers and suppliers of small-scale AD plants together, a suggestion of staging a 'Challenge' has been made.

This would involve encouraging technology suppliers to further their development of small scale, modular AD systems that are cheaper to manufacture and easier to install and operate on farms, as well as raising farmer awareness that this type of system exists.

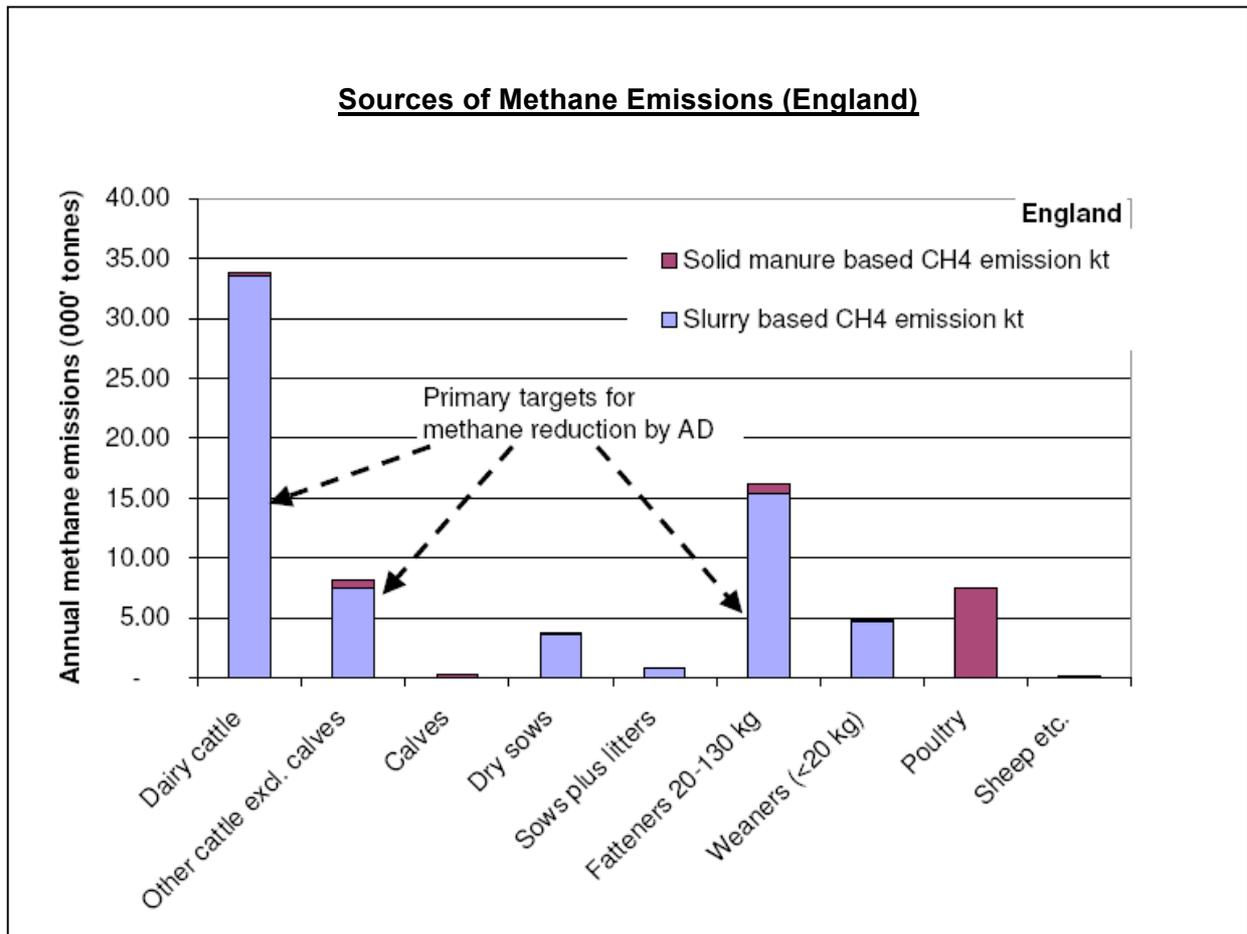
This report provides evidence that these systems do exist on farms in the UK, but that there are also a number of other regulatory and financial issues that still have to be addressed in order for the technology to become widespread.

4.1 Background to the Challenge

AEA Technology have recently reviewed the economics of on-farm AD plants in the UK in the light of the current economic incentives offered by the Feed in Tariffs (FITs)²⁴. The analysis focused on dairy and non-dairy cattle, fattening pigs and broiler chickens, as these are areas where the greatest GHG emission savings can be achieved, but also where the case for AD will be more attractive, as can be seen from the figure below (taken from a 2005 DEFRA study²⁵).

²⁴ Bringing small scale AD to UK farmers – the challenge; Paper presented by Prab Mistry (AEA Group) & Ian Smith (RASE) at the European Bioenergy Expo and Conference; Stoneleigh Park, Warwickshire, UK; 6 - 7th October, 2010.

²⁵ http://www.ifr.ac.uk/waste/DRAFT%20Pgs/docs/DEFRA_methane_mgt%20_rep.pdf



The model used a simple capital cost correlation which was based on the farm digesters installed in the last eight years but all costs adjusted for the year 2010. The annual operating cost was taken to be 5% of the capital cost and the wholesale price of electricity (to sell to the grid) was taken as 4 p/kWh alongside 11.5 p/kWh as the FIT rate. Overall, the costs and revenues were considered to be conservative.

A set of runs were carried out to examine the impact of the current FIT level for electricity (at 11.5p/kWh), but also how non-grazing (or the timing of housing) and capital cost reduction (of 20% and 40%) would impact on the number of viable on-farm AD plants. Livestock numbers for each farm were used to estimate the size of digester required and therefore the economics of the overall plant. Each farm scheme was then sorted according to its economic potential (IRR) and those with positive IRR values were analysed further.

4.2 Key Outcomes of the Analysis

Based on this model, it is interesting to note that, with current farming practices, current AD plant costs and current levels of FITs, the model shows that *only 3.5% of UK dairy livestock would be linked to economically viable on-farm AD plants*. The data further shows that this is where AD technology is most needed to address slurry management issues and reduce methane and CO₂ emissions.

A detailed discussion of the analysis is attached at Appendix A – The Low Cost AD Challenge - which also shows that, no matter what parameters are varied, the mean CHP

generator size varies from 17kWe to 56kWe, in a size range where the cost per kW is still disproportionately high. Note, too, that these are an order of magnitude smaller than the threshold (of <500kWe) that is currently applied by DECC to smaller scale AD plants. At time of writing, a further 'small scale' band of 250kWe had been proposed – still very much larger than the band needed for actual UK farms which has been illustrated here.

The model further shows that:

1. The greatest impact from capital cost reduction will be on dairy farms;
2. A capital cost reduction of 40% increases the number of viable dairy farm projects twenty fold. The number of dairy farms with viable AD plant increases from around 50 to 1100 with all year housing, however, it is recognised that all year housing may not be practically feasible or appropriate in some cases;
3. Doubling the FIT would give a further fourfold increase in viable AD plants;
4. The pig and egg laying poultry farms will also benefit (positive returns on AD plants remain roughly the same – with around 1,000 pig farms and around 150 poultry farms). So in total up to around 6,000 on-farm AD plants are possible.

The overall analysis shows that by far the largest impact will be on dairy farms and therefore the initial focus for the low-cost AD development challenge should be on dairy farms.

5 Case Studies

In order to illustrate some of the benefits from on-farm AD as well as the barriers to its wider development, the author of this report was asked to produce a number of case studies that showcase the experience of farmers who have invested in AD. This section summarises the experience gleaned from the case studies, while the actual case studies are included in Appendix B – Case Studies.

Having used the AEA model to identify the types of farms where a reduction in capital cost and/or an increase in incentives is likely to make the largest impact on the uptake of on-farm AD, it was decided to speak to the primary stakeholders, the farmers with AD experience, in order to identify any other real world factors for the limited uptake of the technology.

These case studies provide a voice for the farmers who have actually integrated anaerobic digestion into their farming practice and are perfectly well aware of the myriad benefits of the technology, as well as the drawbacks. This collective voice is seldom heard by other farmers who may be considering investing in AD.

Perhaps more importantly, their experience of both the pros and cons of the technology is only heard at regulatory and Governmental levels through a very small number of hard-working representatives from farming bodies, such as the Country Landowners Association and National Farmers' Union. These voices can be overwhelmed by the plethora of opinion from other stakeholders such as Local Authorities, the waste industry, suppliers of large scale AD technology, waste and environmental regulators, legal consultants, health and safety interests, the wider energy industry and officials and opinion formers that shape Government policy.

However, amongst all the debate and diverse views, two key facts stand out:

1. With UK food production being heavily reliant upon fossil fuels, which are inexorably rising in price, the country can no longer afford to waste the energy and nutrient potential from organics such as slurries and food waste. In simple terms, farm slurries and manures equal the volume of all the other organic substrates put together and anaerobic digestion is widely recognised as being an excellent method of treating these feedstocks;
2. Whatever method is used to deal with these organics, they must, by definition, be returned to land in one form or another, in a way that minimises pollution and risks to human health. AD is the ideal technology to help mitigate these risks. Anaerobic digestion should not be regarded as a waste treatment solution, but rather as a technology for extracting value (in the form of energy and nutrients) from these previously discarded and undervalued materials.

Therefore, it is critically important that the voice of the agricultural industry, custodians of the majority of the land to which these organics are (or should be) returned, is heard loud and clear.

The farms and individuals who have real-world experience of running an on-farm AD plant and who have kindly agreed to contribute their experiences are listed below. Some are

happy to speak about the technology and to show people around but some have asked to remain anonymous, as they are unable to deal with enquirers. Each is unique in its own way.

1. Colin Rank – Kemble Farms: An on-farm digester based on dairy cattle slurry and maize silage but also using glycerol as part of its range of supplementary feedstocks;
2. Stephen Temple – Copys Green Farm: The Farmers Weekly Green Energy Farmer of the Year 2010, with a digester that is part of a number of energy saving measures;
3. Trevor Lea – Hill Farm: A 22 year old digester on a low-input organic dairy farm, which provides fuel to meet the farm's cooking and heating needs;
4. Wyn Evans – Caerfai Farm: A 32 year old self-built digester, part-heated with thermal solar on a farm with other renewables (PV, wind turbine, ground source heat pumps);
5. Richard Tomlinson – Lodge Farm: A two year old digester using highly gritty feedstock and a unique low parasitic load de-gritting system. There is also a small 500l 'baby' digester on the site for trials;
6. Colin Risbridger – Tuquoy Farm: Three digesters, one of which was retrofitted under a cow shed. The initial digester project identified a need for a standard governing the return of digestate to land (which subsequently became PAS110). However, this standard is still not accepted by Quality Meat Scotland, who continue a partial refusal to accept land application of digestate with non-farm substrates;
7. Worcestershire Digester: A simple, highly automated digester system where the farmer does not handle slurry from the time it leaves the cow to when it arrives on the field;
8. Shropshire Digester: Another simple digester system where the gas is used locally to heat a very large house, but the farmer leaves the operation entirely to third parties;
9. Clive Pugh – Bank Farm: Two operational digesters, one of which uses a unique three stage system to optimise gas output. There is also a covered post-digestion storage stage that is used to minimise emissions to atmosphere, prevent water ingress and act as a gas scrubbing system;
10. -13. Scottish Executive funded digesters: SEC: Wesley Millar – Ryes Farm; SEC: Brian Smallwood - Corsock Farm; SEC: Jim Drummond - Castle Farm and SEC: Frank Kenyon - New Farm, plus 3 others (not interviewed). All used the same technology (in varying sizes). Funding for these was provided by the Scottish Executive as part of a range of pollution control measures;
14. Devon Digester: Self build digester where the primary feedstock is grass silage and chicken muck.

In these case studies, attached at Appendix B – Case Studies, much of the content has been quoted directly from the farmer, either via interviews or direct submission via a questionnaire.

Hopefully, the Government and other stakeholders will listen to the messages that have been derived from the interviews with these on farm AD pioneers. Their years of accumulated experience, along with frustration with regulators and lack of support, can help to provide the solutions for those who are keen to see the widespread adoption of smaller scale AD on farms, not only as part of an effective slurry management strategy, but also to ensure that better use is made of valuable organic resources that are currently not being fully exploited.

6 Discussion of Key Barriers

In this section, a number of barriers are discussed that have been discerned from the case studies in Appendix B below.

6.1 Regulation and Planning

The greatest challenge for those building digesters in recent years has been the plethora of growing and changing legislation, interpreted and applied differently on almost every project.

The case studies illustrate the relative ease with which farmers of 10-20 years ago were able to install a digester as part of their farm slurry management system, in order to help prevent pollution. Comments such as *'I just put in a normal tank to deal with my slurry, like any other tank on the farm—where's the problem?'* were not uncommon in this group.

On the other hand, immense frustration can be seen from the comments made by recent converts to the technology, as they tried to come to grips with regulations. Comments such as *'I can feed my cows things I cannot feed my digester'* or *'if there is any doubt [on interpretation], the answer [from the authorities] is no'*.

By its nature, AD straddles a number of disciplines and therefore a number of regulatory bodies, including European legislation, the Environment Agency, DEFRA, Animal Health, planning authorities and, for larger AD projects (with CHPs), DNOs, Ofgem and DECC. If the project is in an environmentally sensitive or populated area, the list of stakeholders becomes much larger and, in general, their awareness of the benefits of the technology much more limited.

“The key drivers to on-farm AD should be to reduce the carbon footprint and minimise environmental problems (in terms of emissions and run-off) associated with storage and spreading of 90 million tonnes of slurry.”

Whilst most of these bodies agree that anaerobic digestion is the best way to treat slurries on farm, the heavy handed 'waste' rules are a factor in restricting the growth of the UK's AD industry, as farmers find the regulations surrounding the installation of plant, the use of small quantities of gas-improving feedstocks and the use of digestate too expensive and complex to negotiate. After discussion with stakeholders, a number of bodies, including the Environment Agency, are revising their position on a number of points, but there is still a great deal to be done.

A discussion of the specific regulations is outside the scope of this report. However, if the key drivers to on-farm AD are to reduce the carbon footprint of livestock farming and to minimise the environmental problems associated with storage and spreading of manures and slurries, then surely it makes sense for regulation to be minimal and for the financial incentives to positively encourage the technology—it merely requires political will.

This political will is entirely possible. From the case studies, it was painfully obvious that the only digesters built in the last decade where the farmers did not have to deal with any red tape were the Scottish digesters, for which the main driver behind the project was the Scottish Executive.

These digesters were built in an area with holiday caravans and bird feeding sites; one farmer pointed out that, under any other circumstances, they would not have been built. This would have been due to the cost to the farmers of overcoming the associated planning and operational hurdles in these areas, even though prevention of pollution to the holiday bathing waters was the reason for the installations.

Whilst the Scottish farmers, aided by the SEC, had no planning difficulties, other projects do suffer those problems. Although only one of the case study interviewees highlighted any significant problem with planning, there is evidence to suggest that there are wide variations of AD awareness and expertise amongst planners across the country – some simple projects sail through, supported by environmentally-aware planners and others become tied up in red tape and appeals, with farmers and AD suppliers footing the bill for educating the planners and other stakeholders, with varying degrees of success.

It has been suggested that planning policy guidance should be amended to be clearly in favour of smaller scale AD on farms, citing what is and is not acceptable, so that it may be considered by planners directly, rather than using independent subjective and ambiguous interpretation of existing policy guidance.

One bemused correspondent pointed out: *“I would have no problem putting up a slurry store. Take the same tank, with the same contents, cover it, heat it and capture the same emissions and I am hit with ‘NO’ at every turn. And I am only trying to do the environmentally responsible thing!”*

6.2 Type and Scale of Current Incentives

The key drivers to on-farm AD should be to reduce the carbon footprint and minimise the environmental problems (in terms of emissions and run-off) associated with the storage and spreading of 90 million tonnes of slurry. However, the current incentives, developed via the renewable energy industry, do not fully support these drivers.

If farmers are to fully and economically utilise their slurries in an environmentally friendly manner, the main incentive currently available is the Feed-In Tariff (FIT). The FIT, administered by DECC²⁶, does *not* encourage farmers to reduce pollution or their carbon footprint, but rather pays them to generate renewable electricity using a combined heat and power plant (CHP) which runs off biogas from the AD process. Currently, there are a number of appreciable difficulties with installing AD and CHP. These are discussed in the technology section below.

The current FIT level is 11.5p/kW for AD plants generating under 500kW of electricity²⁷. As already noted, this engendered considerable disappointment in the UK AD industry when the scheme was announced, due to the low levels of the FITs and lack of banding for ‘small-scale’ AD, especially when compared with technologies such as solar PV. Additionally, regulations encourage the use of ‘on-farm substrates’, usually energy crops. Thus, the FIT

²⁶ Department of Energy and Climate Change – the government department which brings together energy policy and climate change policy

²⁷ At time of writing, a further band under 250kWe had also been suggested at 14p/kW.

banding level and the regulatory framework is skewed towards larger AD operations with access to significant amounts of slurry and on-farm substrates.

Whilst any incentive for the technology is welcome, it should also be noted that this incentive puts pressure on operators to maximise their gas yield in order to create the maximum amount of electricity. Where energy crops are used in order to maximise this yield, digestate should be kept in a covered post-digestion storage tank in order to capture any emissions, as even small amounts of residual methane emissions from the digestion of energy crops negates the GHG saving from the renewable energy produced.

If FITs are going to be the primary incentive for on-farm AD, the following table illustrates the need for higher level incentives in smaller bands in order to support the technology at the scale which is actually present in the UK.

Potential Output	Feedstock	Notes
500kWe	Slurry from 5000 dairy cows housed year-round	This size of farm currently doesn't exist in the UK
50kWe	Slurry from 500 dairy cows housed year-round	This is a large UK dairy farm; but year round housing may not be typical
10kWe	Slurry from 100 dairy cows housed year-round	This is a typical dairy farm size, but year round housing is not typical
20kWe	Slurry from 100 dairy cows housed half the year, plus Maize silage from 10ha	This would be a typical UK dairy farm, typically housed, supplemented with an energy crop or similar

From the table, it can be seen that:

1. The current banding of 500kWe is set much too high and the proposed band of 250kWe is equally too high for the normal scale of farm present in the UK;
2. If an average farm housing cows for half the year has limited access to on-farm feedstocks, or is unable/unwilling to fund the regulatory costs of accessing off-farm feedstocks, using the biogas in a CHP will not be a cost-effective option.

The case studies illustrate that, for many of the average sized farms in the UK, direct use of the biogas²⁸ from the AD

“The incentives for AD should make it at least as attractive as simply putting up a slurry storage tank which still has slurry handling, pollution and GHG emission problems.”

²⁸ The biogas is used in boilers, Agas, Rayburns or similar to heat the house, hot water, dairy, dairy washings and other buildings as needed, as well as the digester itself

slurry treatment system is a simpler and probably more cost-effective option. This is because of the seasonal availability of much of the primary feedstock (slurry) and the cost, complexity, consistency of gas production and connection issues surrounding the use of CHP with AD.

Unfortunately, the only incentive that direct gas use is likely to attract is the Renewable Heat Incentive (RHI) which again has not been specifically designed for this sector and is therefore unlikely to provide sufficient income (at 6.5p/kWh) to make it economic for many of these farmers to install this simple AD system. On smaller digesters, a relatively larger proportion of the biogas is used for digester heating and this use is unlikely to attract the RHI. This is in direct contrast to FITs. For example, if an AD plant generated 20kWh and the plant itself used 15kWh, FITs would still be paid on 20kWh. However, the RHI, specifically designed to reduce carbon emissions, will not pay incentives on the gas used for digester heating, even though (where slurries are used) that carbon would otherwise largely be emitted to atmosphere if it were not used to heat the digester or the house.

It could also be argued that the RHI might further discourage the use of slurries as a feedstock, since it takes more renewable gas to heat the slurry than to heat an energy crop for a given gas output, so the incentive is reduced if slurries are used instead of energy crops.

However, the RHI is likely to improve the economics of larger scale plants with CHP units, as it will encourage more effective use of biogas energy where possible.

When a farmer is faced with making a capital investment decision for a new slurry management system, the incentives for AD should make it at least as attractive as simply putting up a slurry storage tank which still has all the slurry handling, pollution and GHG emission problems.

In order to be appropriate to the drivers for on-farm AD, in due course, the incentive system should be adjusted to be based on the net carbon reduction that is achieved, although it may still be necessary for some banding to promote smaller scale rural projects.

6.3 Lack of Access to Capital Grants and Finance

If current levels of FITs are too low to make AD attractive to the majority of farms (especially when compared with the cost of installing a simple slurry tank), what can be learned from the case studies, in terms of access to capital?

Nearly 93% of the digesters surveyed had some form of capital subsidy, either from simple guaranteed grant applications for pollution control or from grant funding. The latter was a much longer and costlier process, where a positive outcome was not guaranteed and there is also concern that the limited incentive payments available may be withheld if AD plants are grant funded, under EU state aid rules.

Of the approximately 30 farm digesters built in the late 1980's and early 1990's²⁹, all took advantage of the 30%-60% farm pollution abatement awards. This also had the secondary effect of creating a fledgling UK farm digester industry and a number of design innovations,

²⁹ Those that the author is aware of.

both in terms of technology and price. However, the UK AD design industry stagnated when these incentives were withdrawn in 1995. It is now dominated by non-UK suppliers.

Conversations with a number of the farmers in the case studies, as well as indications from industry sources suggest that many farmers at this scale are simply not financially able or willing to go through the time-consuming administrative processes involved with applying for complex grant funding with a nominal chance of a positive outcome. Hence the incentives for smaller scale AD plants (for community projects as well as farms) need to be higher.

If European and UK Government policy is to remove capital grants and subsidies for treating slurry, how else might farmers fund the capital cost of building an AD plant?

A proportion of farmers surveyed, as well as evidence from industry, indicate that there are difficulties in accessing traditional routes for finance in order to build a digester. A number of factors come into play. These include:

- Age of the farmer: The average age of farmers has been steadily rising, so that by 2007, 62% of farmers were aged 55 and over³⁰. Lenders tend to impose additional restrictions on older borrowers in order to secure the debt over the repayment term;
- Farm Income: Since the early 1960's farm income has steadily declined, only picking up within the last decade or so. However, in 2009, Net Farm Income was calculated at £20,600, less than the UK median of slightly over £22,000³¹.

"Banks aren't prepared to accept revenue from Government support schemes, whether they be FITs or ROCs"

-R Carter

Whilst these figures can vary considerably (for example, the Farm Business Survey quotes a 2009 income of £43,011), without a doubt lenders will look at the ability of the business to repay the loan and place extra conditions, likely in the form of security. Not surprisingly, farmers may be unwilling to put their whole business in jeopardy in order to install an AD system when the seemingly cheaper alternative is to install a new slurry storage tank or other simple slurry handling systems.

By far the biggest factor in finding funding for AD plants stems from recent tribulations in the banking sector. Most banks now are unwilling to finance plants, even when farmers have significant equity to provide as security.

Richard Carter, a consultant experienced in putting together AD projects, said *"projects have got to the stage where there is planning, EA Permit Exemptions in place, grid connection, input feedstock, output landbank, detailed quote, business plan, cash match funding and still not got funding from the bank. Banks aren't prepared to accept revenue from Government support schemes, whether they are FITs or ROCs"*.

³⁰ http://www.ukagriculture.com/statistics/farming_statistics.cfm?strsection=Holder's%20Age

³¹ http://www.ukagriculture.com/uk_farming.cfm

To get to this stage is an expensive, time-consuming and frustrating business, both for farmers and potential plant suppliers. Plant suppliers have no choice but to add these significant overhead costs to the capital cost of the AD plants which they supply.

There is also a certain degree of distrust of the technology on the part of banks and there are instances of them setting stringent and costly conditions on the finance. This might include some kind of third party project management or 'expert' assessment, incurring additional costs of up to 15% of the capital cost of the project.

This is evidently not cost effective on a small scale nor, it could be argued, sensible. As the UK has very few people capable of making an assessment on the engineering, process and farm integration elements of a successful digester project, experts are normally drawn from related fields and their conclusions are not always appropriate to either the scale or the type of technology.

Letcher³² proposed a rolling loan programme with favourable terms (e.g. lower interest rates, initial payment holiday, etc) to make capital available to such installations, suggesting the initial funding be provided by current environmental taxes, Government and retailers such as Sainsbury's and Tesco, as part of their environmental and Corporate Social Responsibility (CSR) obligations in reducing the carbon footprint of their supply chain. This would not be money 'spent' but money invested, as repayment of the loan replaced capital for further loans.

6.4 Restriction on use of Imported Feedstocks

Unless a farmer wishes to go to the extra time and expense of selling digestate, the primary limiting factor to the size of a digester is the land base available for digestate spreading, so most farms are physically unable to take in significant amounts of off-farm organics. By definition, this means that they cannot turn into a 'waste processing plant' because they are limited by the amount of nutrients they can spread back to land. However, supplementation of such substrates can significantly improve the economics of these digesters by eliminating the need for fossil-fuel derived fertilisers, especially where livestock are only housed part of the year.

“Why should we have to grow energy crops in order to be able to treat our slurry when there are plenty of local organic feedstocks?”

Of those that responded on this issue, roughly 92% of correspondents regularly/occasionally use/have used higher strength organic feedstocks, grown on the farm or sourced from off the farm, to improve their biogas production or because the feedstock is readily available.

Feedstocks used included products like chicken manure, bread making by-products, cheese making co-products and apple pomace, as well as high energy by-products like glycerol (from biodiesel production facilities). Chicken manure is generally considered to be too rich and unbalanced a feedstock, due to its very high nitrogen content, but lends itself to co-digestion with other slurries and wastes. Additionally, chicken farmers may not necessarily

³² Waste 36 Submission to the Waste Strategy for England 2007-Vol II

have the landbase for spreading of digestate, so addition of this relatively high strength feedstock can improve gas production and the economics of slurry digesters.

A significant proportion of digesters have used glycerol on occasion, but now are required to refuse a regular source of locally produced glycerol because they cannot bear the cost or hassle of the administrative burden associated with using it. Hence available glycerol is now shipped hundreds of miles to Europe—a seemingly unnecessary additional carbon cost to a by-product from a renewable energy (i.e. biodiesel) plant.

The AEA model illustrated that, in order to make digester installation a reasonable prospect for more than 3.5% of dairy cattle farmers, capital costs of the AD plant would have to reduce significantly (discussed below) or FITs would have to double. However, such changes would still only increase prospective AD plants to link with some 18% of dairy cattle in England.

Farmers also have the option of growing energy crops such as maize in order to improve the economics of the digester. Whilst this avenue might be possible for some, many of the smaller farms in this survey fully used their land for grazing and fodder crops for their cows.

Others were aware of potential negative public opinion from growing energy crops. One or two expressed amazement as to why they should have to grow energy crops in order to fund the treatment of what was essentially a slurry problem. The 2009 Farm Business Survey³³ indicates that a typical medium sized dairy farm in England is about 128 ha with 135 milking cows plus followers. The Institute of Organic Training & Advice notes that 1.28 LU (livestock units) per hectare is the norm on a 'sustainable system' (with minimal outside inputs)³⁴.

Based on these figures, the typical dairy farm with close to the average number of livestock units is unlikely to have spare land to grow energy crops, especially with rising costs of buying in feedstocks. The cost of buying in concentrate is 3.5 times the price of grass³⁵ and, as this price rises, there will be more pressure on land for grazing/feed and less appetite for energy crops at this scale.

Whilst smaller AD plants that digest slurries are keen to improve their gas yield with higher strength feedstocks, poultry farmers that run broiler operations can struggle to get rid of their chicken manure if they have a limited land base. However, accessing these substrates results in considerable (and disproportionate) costs in acquiring the necessary permits.

Finally, studies by WRAP and DEFRA indicate that there are problems with high ammonia concentrations for food waste only digesters and recommend blending food wastes with feedstocks like slurries to stabilise the process and to minimise the environmental emissions of ammonia from pure food waste digestate.³⁶ All other considerations aside, from a purely

³³ <http://www.farmbusinesssurvey.co.uk/regional/commentary/2009/southwest.pdf>

³⁴ Dairy Cow Nutrition, Dr Mike Tame, www.organicadvice.org.uk

³⁵ Pat Dillon, Moorepark Dairy Production Research Centre from <http://www.thedairysite.com/articles/2120/practical-aspects-of-feeding-grass-to-dairy-cows>

³⁶ http://www.wrap.org.uk/downloads/Operators_Briefing_Note.f9e8d7de.10413.pdf

process optimisation viewpoint, as well as with regards to 'food waste miles', it makes sense to process food waste in a local digester, since the residues have to be land applied.

Unfortunately, the extra cost of building a food waste digester, plus the costs of compliance with current legislation limit the willingness of farmers to consider this option and uptake of AD at farm scale is further restricted. However, a model suggested by a number of industry experts³⁷ may provide a way forward. In this Hub and PoD³⁸ model, food waste is processed and pasteurised at a hub, removing potential pathogens before distribution to farm AD sites.

6.5 Utilisation of Digestate

British farmers have traditionally sold and continue to sell small quantities of composted horse or cattle manures. Similarly, over the years, farmers with digesters have sold or made available digestate to neighbours, friends and local gardening clubs, and received reports back of scores of medals being won based on excellent natural sources of nutrients.

This has the dual effect of engaging the non-farming community with local farmers, at a time when farming is not well understood by a growing proportion of rural dwellers. In the cases where digestate is supplied to the local community, it provides positive stakeholder opinion and community support should planning be sought for another digester in the vicinity.

Under current legislation, it would appear that the local supply of digestate is not possible without complying with further rules and, subsequently, further costs. As all of the farmers interviewed need to use the greatest proportion of the digestate on their land, the time, money and effort required to comply at this scale is excessive.

6.6 Reliability of Technology

On farms that installed combined heat and power (CHP) gas engines to generate electricity, all highlighted problems with the technology to varying degrees. Having overcome hurdles with grid connections and OFGEM, a number of them had problems with the unit itself.

Lodge Farm and Kemble Farms were slowly modifying their units to reduce unacceptable levels of downtime. Copys Farm decided to replace the CHP supplied after a very short period of operation and Clive Pugh had load balancing problems. The only Scottish digester with a CHP abandoned it because of technical issues.

Whilst it is generally agreed that CHP is the most efficient use of gas (especially on farms where there is too much gas to use directly), it would appear that there is still considerable room for improvements in the technology at this scale. Further points made by interviewees included:

- A variety of difficulties with connecting to the grid, including inability or unwillingness of DNO's to prioritise smaller renewable installations, load balancing problems,

³⁷ Including V. Heslop, AD Technical expert and part of the team for the ADQP; Richard Northridge, community micro-AD & composting expert, Professor Charles Banks, University of Southampton and others.

³⁸ Point of Digestion

distribution network capacity issues and limited generating capabilities when farmers only have access to a single phase electricity supplies;

- Unrealistic capital cost of grid connection, with quotes from around £10,000 to several hundred thousands of pounds;
- The capital cost of a CHP unit, typically up to 25% of the capital cost of digester, with the cost generally being in excess of £1000/kW at this smaller scale;
- The unreliability of CHP running, with owners struggling to achieve anywhere near 90% up time;
- Significant extra maintenance costs when compared with a digester alone;
- Additional costs of engineering the digester in terms of gas scrubbing, monitoring and achieving steady state gas production in terms of quality and quantity of gas.

Also, for the great majority of British dairy farmers, cows graze outdoors for at least half the year. Where gas is used directly to heat houses, AD works well, as gas is created and used in winter. For CHP installations, further feedstocks are required to justify the extra cost of a CHP unit and if sufficient organic feedstocks are not available on-farm, there are extra purchasing and regulatory costs for obtaining outside organic substrates.

A few correspondents had identified problems with pumps and macerators. Solutions varied from the simple (using a Stilson to coax a slightly undersized pump into motion) to the more complex (modifying a feed system to incorporate an additional pump). One had mentioned a foaming problem in the 'learning phase', but had coped with this. Most digester operators who had occasional silting problems dealt with these as a matter of course.

Injecting the gas to grid is not economic at this scale because of the high capital cost of the upgrading equipment; however, in appropriate circumstances (i.e. CHP is not an option and gas production is in excess of what can be used directly on-farm), there may be an argument for looking at the economics of other models such as mobile upgrading units or 'dirty' lines to centralised upgrading facilities in areas with several co-located digesters.

6.7 High Cost of Technology

Simple economic models, as well as wider AD industry views, generally expect that, if the appropriate incentives to build AD plants exist, the market will respond with appropriate advances in technology and reduction in unit digester costs.

By quite some margin, the total cost of a digester is not the cost of the actual components: it includes the overheads involved in the selling process. Some of these costs have already been touched on, but they include costs relating to fielding and investigating initial enquiries; producing or contributing to feasibility studies, providing technical support at public meetings, educating planners and other regulators, understanding interfaces between third parties (such as DNOs) in order to inform the plant design, producing or contributing to business plans and grant applications, informing grant appeals, informing planning appeals, creating detailed quotes and revisions of detailed quotes, justifying the technology to experts on grant application boards and other funding bodies, understanding and dealing with regulation and legislation and participation in consultations and lobbying. As already pointed out, it is not

uncommon to get to an advanced point in the project life cycle, only to have it fall through because of reasons such as a failure to secure debt funding.

This is illustrated by the fact that even well-established European companies coming to the UK had modest targets of building one or possibly two digesters in their first year. That is a lot of overhead to pile onto a project (or store up for future projects) and is only possible on plants with a significant capital value. The only way for digester suppliers to provide low cost, small scale digesters is to minimise overheads and maximise the number of digesters sold.

By positively removing the many obstacles and making it clear to farmers that they are being encouraged to invest in a digester, the market will expand and units will become cheaper.

The simplest of the case study digesters consist of an insulated tank, a way of heating the tank (at this size, typically a boiler), a gas holder, a mixing system, and some pipework, with the possible addition of pumps or augers. If not already present, a method of using the surplus gas may also be necessary, such as an Aga, Rayburn or boiler. This equipment on its own is not impossibly expensive but in fact is simple, common, standard, proven technology. During the 80's and 90's, both Farmgas and WRI had inexpensive, modular and easily installed units which met this need.

To this simple basic system, complexity and cost can be added in as appropriate. The next 'level' of digester complexity in the case studies tended to have separation and a simple control system. With the addition of a CHP unit, extra cost is incurred because additional maintenance, gas scrubbing, monitoring and control is necessary to ensure a continuous flow of gas of sufficient quality - however, it is hoped that the increased cost is justified by increased revenue from electricity generation. Most respondents in this category had access to other on-farm or brought in feedstocks and were projecting reasonable payback periods of between 5-8 years. The RHI is likely to also help improve the economics of such digesters where heat can be used on-farm.

6.8 Lack of Stakeholder Awareness of Small-Scale AD Technology

This report has already highlighted a lack of familiarity with, and confidence in, AD technology and the benefits of AD by planners, regulators and financiers. However, farmers themselves are often unaware that technology exists to suit their needs. AD presentations and the farming press are understandably full of impressive, large, glossy and expensive AD plants. In contrast, some of these smaller older digesters which have worked faithfully for many years and have lost their shiny newness will not find their way into press coverage of the industry, presentations and awareness-raising courses for interested farmers, who therefore often feel that the technology on offer does not fit their modest scale.

If the handful of case studies illustrated in this report are not enough to demonstrate that the technology works on a variety of scales, then the large numbers of German, Danish and other European digesters in addition to the innumerable very small digesters in communities across countries like India and China clearly demonstrate that the technology works.

As with any emerging industry, there will be accidents and failures and, whilst it is sensible and desirable to try to minimise these, the important thing is to ensure that the economic and regulatory conditions allow them to be built in the first place. Confidence in the technology

will grow if the industry is allowed to grow and excessive layers of complexity and bureaucracy are avoided.

6.9 Summary of Barriers

It would thus appear that a reasonable proportion of farmers hoping to invest in small-scale AD systems have few choices when trying to justify the cost of AD technology, bearing in mind that:

- incentive levels and banding may not be sufficient to make AD an attractive enough proposition when compared with simply putting up a slurry store (with all its attendant pollution problems);
- FITs are currently the main incentive for farmers to treat their slurry problem and this involves the addition of a CHP plant to create electricity. The RHI should improve the economics of these digesters where heat can be used. However, for direct gas use, the RHI is unlikely to make a significant impact on the economics at this scale, as a relatively significant proportion of the gas is used to heat the digester—and this use would appear to not be covered by the RHI;
- currently, electricity generation using FITs and small scale CHP has a cost premium in terms of increased £/kW capital cost, extra annual maintenance, reliability issues, increased digester complexity, consistent quality gas production and grid connection problems;
- small farms may not have the land base to grow energy crops to improve digester economics and there will likely be increasing pressure on any available land to be used for cattle grazing/feed as costs of inputs go up in line with rising fossil fuel prices;
- the time and cost required for applying for bespoke permitting to bring in local higher strength feedstocks is disproportionate to the relatively small amount of feed brought in and the regulations are not flexible enough to consider innovative models such as the 'hub and PoD';
- capital costs of digesters are unlikely to come down significantly, at least until there is a more active market and overheads from regulation/planning are reduced;
- access to capital has become increasingly difficult.

7 Discussion of Benefits

Anaerobic digestion is ideal for minimising environmental problems and creating renewable energy. However, most farmers in the case studies viewed AD technology as a multi-faceted package with a myriad of benefits, where no individual benefit on its own could justify the installation of a plant, but the combination of benefits helped their farms reduce pollution, their carbon footprint and their fertiliser and energy needs, making the farming operation more sustainable. These benefits are outlined below.

7.1 Pollution Reduction

Anaerobic digestion has the potential to reduce both emissions to atmosphere, as well as watercourse pollution from run-off, for a wide range of feedstocks which currently cause these environmental problems, of which the largest by volume are agricultural slurries.

In line with the best practice AD plants, slurry is scraped into the digester on a daily basis, so GHG emissions such as carbon dioxide, methane and ammonia are kept to an absolute minimum in order to maximise the biogas potential of the slurry.

Furthermore, if slurries are co-digested with other feedstocks which would normally be sent to landfill or stored/disposed of in such a way as to emit GHGs, AD can successfully capture and utilise this renewable energy.

7.2 Improved Slurry Handling

Where livestock manure or slurry is produced, there are always considerations relating to its storage, handling and spreading. The regulations relating to slurry and manure management are becoming more complex and as the burden on farmers increases, AD should be more widely considered as part of the solution.

Farmers who understand the technology laud the benefits of AD, as it greatly improves the ease with which their slurry can be handled. Benefits include:

- Odour reduction;
- Ease of spreading, both the liquid and solids;
- No need to add water and mix in order to pump or spread;
- Improved uptake of nutrients and lower pollution risk (see below).

“With AD, there is no slurry problem”

7.3 Digestate Use

In addition to improvements in slurry handling, all farmers pointed to the improved utilisation and recycling of crop nutrients, with Colin Rank expressing it most succinctly:

“Many minerals and trace elements are fed to the cows which pass through the cows and are returned to the land where they are taken up by the plants grown on them. The availability to both animal and human absorption is greatly increased. Minerals and trace elements are not readily absorbed directly but are readily taken up by plants. Eating the vegetable matter grown

on ground rich in trace elements and minerals results in a high absorption of the minerals in the plants. The farm based Biogas system preserves that important cycle of the mixed farm and is a benefit far more valuable to the population than food grown organically.”

Where solids separation was incorporated into the system, AD digestate allowed the targeting of nutrients for a specific purpose, e.g. between arable and grazing, or nutrient application onto a specific field, as well as targeting the application of soil conditioner.

Interviewees noted further benefits of digestate, including:

- A greater spreading window for land application;
- Reduction of pathogens that can be found in undigested slurry;
- Faster re-grazing – cows can be put out 2-3 weeks after spreading with no problems;
- Weed seed kill – useful on organic farms and for reduced herbicide applications;
- Less likelihood of nutrient leaching into local watercourses than slurries;
- Fibre quickly integrates into the soil; does not taint the following crop or get picked up by cultivation equipment and other farm machines;
- “How well liquor works on grassland”: Trevor Lea pointed out a noticeable and almost immediate effect on plants because the leaves turn darker green due to the improved nutrient uptake;
- “How well digestate works on tomatoes, sweet peas and other garden crops, creating prize-winning produce”;
- The Biological Oxygen Demand (BOD) of slurry is significantly altered by the AD process. In real terms, this reduced BOD means that if the digestate does get into watercourses, it will not pollute to the same extent as slurry, since it does not rob aquatic life of vital oxygen;
- Digestate encourages nitrogen-fixing clover in the leys;
- Smell reduction when spread.

7.4 Displacement of Fossil Fuels

Because of better nutrient recycling capabilities, AD can either wholly or partially displace the use of fossil fuel fertilisers on the farm, both in terms of cultivation and haulage.

Using the biogas directly in a boiler, Rayburn/Aga or a CHP unit can create further savings when used in the following situations:

- use in district heating or on-farm commercial uses (e.g. polytunnels or glasshouses);
- hot water in the dairy (or elsewhere on the farm) or for domestic hot water/heating;

- heat used to supplement an on-farm or local process such as cheese making or grain/green crop drying;
- heat can also be passed through a heat exchanger and used for cooling purposes, such chillers for dairy products or use in the bulk milk tank;
- generating renewable electricity.

7.5 Sustainable Farming, Food Security and Farm Diversification

Many farmers continue to search for opportunities to diversify their income base and this has been actively encouraged by a succession of Governments. The pressure on farm incomes are well known and do not require further comment here but this will continue as input prices increase. Farmers should be encouraged to add value to under-utilised organic substrates by using AD.

Richard Tomlinson said it best:

“I particularly like the fact that it gives you a second income stream which is non-food based, out of control of supermarkets and is an income stream which is clearly only going to improve. Any other agricultural activity is largely controlled by supermarkets and the price of production bears no resemblance to the purchase price. By getting into renewable energy, there is a growing market and increasing demand.”

In addition to diversifying farm income, because AD recycles nutrients and reduces reliance on fossil fuels and fertilisers, it helps to make the farming operation more sustainable, thus helping to protect the food security of the nation.

7.6 Increased Environmental Awareness

Over the last 50 years, access to inexpensive fossil fuel-based fertiliser, primarily ammonium nitrate, has led directly to increased yields, but at the expense of inadequate recycling of the increased nutrient levels generated by livestock farming - slurry is seen as a 'problem'.

This has led directly to the need to impose Nitrate Vulnerable Zone (NVZ) legislation which impinges on the spreading of slurries when, to a much greater extent, the actual problem has been caused by the use of increased fossil fuel fertilisers. NVZ legislation is attempting to reduce the impact of this. But it is clear that all farms in the study with digesters have broken that cycle of pollution and reduced their costs. As one correspondent put it, *“We have re-written our business plan three times and every time it has improved”*, largely due to offsetting fossil fuel costs.

It is apparent from the case studies that farmers who have AD have an increased awareness of the value of their slurries to their farm, especially with regards to smell reduction, nutrient recycling and improved nutrient uptake. They do not regard it as a 'problem'.

These farmers are therefore unwilling to waste this resource, which coincidentally means that they are less likely to pollute, both because the reduced BOD in the digestate reduces pollution problems, but also because they are more aware of and more careful with this resource. A reduced reliance on fossil fuel fertilisers with all their attendant environmental costs also characterises these studies.

7.7 Successful Integration of Digesters on Farms – Key Features

It is true that, in such a fledgling industry as the UK, digesters have failed to make the impact that has been generated elsewhere in the EU. However, even in well-established industries such as those in Germany and Denmark, digester projects have failed for many reasons.

However, it is worth collating the experiences from farmers successfully using AD and, with this multi-disciplinary technology, their points are sometimes obvious and sometimes surprising.

1. **Minimise rain ingress** to the slurry. Heating a substrate which has no biogas potential is a waste of energy and a waste of digester space and can significantly affect the economics of digestion in terms of gas output per m³ of substrate loaded;

2. **Maintain the biogas potential** of the feedstock. In the case of slurry, it is vital that the slurry gets into the digester as quickly as possible for two reasons: if it has not lost too much heat, less energy is used in re-heating up the slurry but, more importantly, it minimises the loss of biogas potential from the substrate.

Studies have shown that this potential can be lost in two ways: by oxidation and by methane emission. Where the surface area of the tank is large, such as those under slats, there are significant aerobic CO₂ emissions, as well as CH₄ emissions from lower down the substrate which is anaerobic, with both processes causing loss of methane potential.

Wyn Evans noted that his digester produces extra gas within 2 hours of putting in whey, an effect that lasts for nearly 24 hours. He also had experience of the amazing biogas potential from small quantities of (grass) silage runoff – it is for this reason that systems which use silage as a substrate are very careful to maintain the integrity of the silage.

Trevor Lea speaks of the time his cows had some bad silage and he had to open all the windows in the house in mid-winter. Why? Because it went straight through the cows, causing an increase in gas production and a very hot Rayburn!

This can mean the difference between an AD system being economic or uneconomic simply in terms of minimising emissions and maximising renewable energy potential. AD plant suppliers will assess the economics of the plant and size it based largely on their standard expectations of biogas production from given quantities and types of feedstock.

If the feedstock is watered down or degraded, those figures are significantly affected. It can also be seen from the case studies that farms vary considerably in the quantity and type of inputs to the cows (as well as the type of cow) and this also causes variations in gas production.

3. **Integrate the digester into the fabric of the farm.** At this scale, a successful digester must fit seamlessly and effortlessly into the existing slurry management practices of the farm. Slurry ideally goes straight into the digester. Digestate flows out directly into a lagoon or over a separator. The digester is located at the heart of the

farm, so that, like a cow, the farmer can easily and efficiently see that it is fed, kept warm and operational, a task which takes minutes on a simple system.

From a number of these systems, it can be seen that a well-integrated digester creating a product which is easy to handle is integral to the automation and ease of the slurry handling process from cow to field.

On larger systems, the digester may generate sufficient income to warrant paying for a dedicated operator and then, it could be argued, location may become less of an issue.

4. Incorporate redundancy. All of the systems which used gas locally in boilers, Rayburns or Aga also had at least one other form of heating: wood burners with back boilers, immersion heaters, solar thermal, oil boilers. This was normally because the digester was at ambient when the cows were out in summer and extra heat might be needed on a cold day, so a secondary form of heating/hot water was necessary.

Wyn Evans believes that, with the use of solar thermal on the digester, he can significantly extend the use of the Aga (as well as provide heat where needed) and this certainly bears investigation with a view to possible replication.

Maintaining digester temperature is most critical to the process, so most of these systems had a secondary method of heating the digester, both to bring it up to temperature for cows coming in or to mitigate against the 'dreaded digester spiral of death'. If a digester is heated solely by its own gas or heat from a CHP and the gas boiler or CHP fails, the digester begins to lose temperature. The lower the temperature, the less gas is produced.

Without biogas, the gas boiler or CHP won't run and the digester fairly quickly sinks into decline. Thus, we see the necessity for an alternative digester heating capability: an alternative diesel boiler, immersion heaters or solar thermal. Bearing in mind that the surface area to volume ratio on these smaller digesters is quite large, it also pays to ensure that the digester is well insulated.

5. Monitoring and keeping appropriate records. Monitoring can add complexity, cost and potential for breakdown and should not be done needlessly. There is no 'one size fits all' when it comes to monitoring or record-keeping. Academics, biochemists, process engineers and regulators like to monitor everything and this is appropriate for trials and studies.

Those who are trying to maximise their digester income, especially when bought-in or high value feedstocks are concerned, carry out careful and detailed monitoring to protect their investment. The addition of a CHP to even a simple or relatively small system requires a certain amount of record-keeping, so that maintenance schedules are followed, electricity output recorded, gas quality checked and down-time noted.

However, without exception, all interviewees who had a non-CHP digester considered that the main thing to monitor was the temperature of the digester. The method of doing this was generally pretty simple and technologically foolproof. One occasionally stuck his hand or a standard thermometer into the hot outflowing

digestate and additionally felt the outgoing and return heat circuit temperatures. Others would glance at the control panel to ensure the lights were green. Where separation was present, as the digester was integrated into the farm, it was pretty obvious if the separator wasn't running; a similar story with inlet augers, weirs or pumps.

Several of those new to AD said that they found it helpful to their learning process to initially record such things as pump hours, digester temperatures, flow/return circuit temperatures and other figures peculiar to their particular system; however, this was generally largely abandoned as they gained experience.

6. Training, Certification and Maintenance. Nobody highlighted operator training as an issue, although several pointed out that there was certainly a learning curve. All interviewees (where applicable) had had varying degrees of training from the digester supplier. Where the plants were relatively simple, there did not appear to be a call for specialist certification.

As the number of plants grows, the requirement for digester maintenance engineers will grow too. Specialists such as Jimmy Ellis, who started out at Farmgas and has almost single-handedly kept a large proportion of the case study digesters running for many years, slowly find themselves joined by others as the market grows.

Interestingly, a couple of the Scottish digester owners felt on one hand that there should have been 'more training' at the beginning, but on the other hand praised digester engineer Jamie Gascoigne for his teachings during his visits. However, this would appear to be more of an issue of engagement rather than training.

7. Farmer Engagement. Farmer engagement with the digester itself is critical. In the words of AD pioneer Les Gornall, *'it is a cow, not a tractor'*. This view was echoed in similar words by a number of farmers. They pointed out that, much like a cow, the digester needs to be fed, kept warm and emptied. It cannot be stressed enough that one of the main (and largely unquantifiable) drivers for success at this scale is that someone on the farm actually cares for the digester and therefore learns to understand how it runs, both from an engineering point of view and as a biological process.

All the farmers interviewed had encountered mechanical/technology issues to a lesser or greater extent, but those with a greater *personal* stake in the running of the digester were more proactive in understanding the problem and finding a solution. It could be argued that an element of this personal stake is financial; however, that is not the whole story, as evidenced by the varying levels of success with the Scottish digesters which were, to all intents and purposes, zero cost to the farmer.

8. Technology. The number of digester technologies is bewildering and extensive: gas mixing versus agitators vs jet mixing; bell over water gas holders vs double membrane, either separately or in the roof of the digester; multi-stage digestion vs single stage; mesophilic vs thermophilic; CSTR vs batch; hydrolysis; addition of enzymes and so on. It is not within the scope of this report to comment upon the merits or demerits of each technology, except to say that again, the engineering technology must be appropriate to the situation.

At this scale, successful digesters must be simple, robust and farmer friendly. The simplest systems had automatic scrapers pushing slurry into a flow channel which gravity fed into a gas mixed digester with no internal moving parts. When separation was involved, digestate was augered out over a separator, the solids falling into a bunker and the liquid fraction being available for irrigation which, in some cases, required little intervention.

The control systems varied from non-existent to a simple small automated system, which was robust and did not require the use of computers. On larger, more complex digesters, especially when CHPs were involved, more sophisticated computer-controlled systems were in evidence.

8 Conclusions and Recommendations

In his foreword to the Renewable Heat Incentive, DECC Minister of State Greg Barker notes that 'we must take action now to protect our environment' and 'we have signed up to carbon reduction targets and have committed to reducing our emissions by at least 80 per cent by 2050'.³⁹

The estimated GHG potential of animal slurries alone is 3 Mtonnes CO₂ equivalent and current farming practice requires slurry to be stored in a manner which does not capture these emissions. Manures and slurries produced on farms are by far the largest tonnages of potential feedstock for anaerobic digestion, with a methane potential of around 10 billion kWh of energy per year⁴⁰.

Unlike other renewable technologies, anaerobic digestion has numerous benefits and can both contribute towards reducing these greenhouse gas emissions, as well as offsetting the farm's requirement for energy and fertiliser. Further important benefits to the farmer include reduced odour, easier handling and spreading, the ability to target nutrients, an increased spreading window, less crop taint, fewer weeds, reduction of pathogens, less pollution potential from run-off due to reduction of BOD, increased nutrient uptake and recycling of NPK, as well as trace elements. Farms using AD become more sustainable, as they not only reduce their exposure to rising fossil fuel costs by producing renewable energy and fertiliser, but they potentially save money due to improved slurry storage, handling and distribution, improved farm hygiene and increased ley life.

Faced with tougher regulations relating to slurry handling, farmers would be more likely to embrace this cost-saving and potential revenue-earning opportunity if:

- the incentives were targeted appropriately for the varying farm scales;
- the regulatory system was more accommodating, especially with regard to using locally available feedstocks and digestate between farms;
- capital finance for the technology was more accessible.

The case studies have shown that farm slurries can and should be digested in smaller scale AD plants located on farms. Because the primary feedstock (slurry) is usually only available for 6-7 months of the year, it may necessitate the farmer to use a range of additional feedstocks that are available locally. However, at this scale, it should be possible for suitable materials to be fed to a digester without the excessive regulation that is currently in place.

With this plethora of environmental and agricultural benefits, a good case can be made for active encouragement of AD at a smaller scale on farms. There are a number of recommendations that arise from the report and the stakeholders that have been consulted during its preparation. These are as follows:

³⁹ Renewable Heat Incentive, March 2011, Ministerial Foreword by Greg Barker, Minister of State, DECC, available from www.decc.gov.uk/rhi

⁴⁰ Ref. Professor Charles Banks, Introduction to this report

8.1 Incentives

- A more advantageous FIT band for small-scale digesters (e.g. less than 200kW and possibly a further band for digesters under 50kW). Farmers should not be precluded from accessing the FIT if they take in outside feedstock types, i.e. the tariff should not be constrained by the supplementary feedstocks used;

Additionally, like income tax, any tariff bands should be incremental, eliminating the possibility of installations which artificially limit their feedstocks in order to achieve the highest tariff. When thermal plants produce energy from waste or biomass they have a fairly well defined electrical or heat capacity; whereas AD is a biological process which requires a degree of design flexibility to allow for variation in quality as well as quantity of feedstock. For example, if the cows are fed a richer diet, the digester will produce more gas and the installation would be forced to flare the excess biogas because it would be more economic to do this than to drop to a lower tariff level—a highly undesirable side-effect. So, if the band were set at 23p/kW for installations up to 50kW, all on-farm installations should receive this tariff, with any excess being subject to the lower tariff;

- On small-scale AD plants, where electricity generation is not practical (and FITs are not available) or because site-specific considerations indicate that biogas should be used directly, there should be provisions in the RHI to allow the payment to reflect the total gas volume produced, since this will accurately reflect the reduction in carbon footprint;
- Incentives should be at such a level as to make AD at least as attractive as simply putting up a slurry storage tank;
- In due course, the incentive system for AD and other rural renewable technologies should be adjusted to be based on the net carbon reduction that is achieved. It might still be necessary for some banding to promote smaller scale rural projects.

8.2 Access to Capital

- There needs to be scope for farmers to access RDPE (the EU-funded Rural Development Programme for England) or similar grants, where they are not being phased out, without affecting eligibility for the RHI on very small on-farm plants;
- Development of new funding models such as a rolling loan programme with preferential terms (for example, along the lines of student loans) should be considered, with options such as lower interest rates and initial payment holidays. The fund could be partly or wholly funded by current environmental taxes, Government and relevant organisations (such as retailers) wishing to reduce the carbon footprint of their supply chain and who enjoy the cost benefits of farms who reduce their GHG emissions and pollution as well as their reliance on fossil fuels and fertiliser. This would not be money 'spent' but money invested, as repayment of the loan replaced capital for further loans. Also it would be helpful if banks were willing to partner with plant suppliers in order to offer assistance with funding;
- The industry also needs to work with the banks and other financial institutions to promote greater understanding of the technology and its potential impact on the rural economy.

8.3 Regulation, Planning and Feedstock Restrictions

- It is necessary to have a light regulatory touch for low-risk organic substrates such as locally available food waste or co-products, plus farm by-products like apple pomace or vegetable processing and sugar beet waste, as well as more complex substrates like high strength poultry manure when they are fed to what is primarily a slurry digester;
- Modification of existing policy to allow the creation of more holistic approaches to the management of feedstocks such as centralised food waste processing and pasteurisation hubs, which can supply pasteurised material to on-farm AD sites (Hub and Point of Digestion (PoD) model);
- Modification of existing policy to allow a light touch on very small (micro) AD for the smallest of farms or acreages, where energy is largely used on the farm and the volume of imported feedstocks are below a 'de-minimis' level;
- Farmers should be able to give away or sell small quantities of digestate to researchers, local gardeners and other members of the community without being subject to disproportionate regulation;
- There should be a single and definitive point of information for regulations surrounding anaerobic digestion, as there are clearly some grey areas and conflicting advice from different bodies;
- Planning policy guidance should be amended to clearly promote smaller scale AD on farms, citing what is and is not acceptable, so that it may be considered by planners directly, rather than using independent subjective and ambiguous interpretation of existing policy guidance.

8.4 Stakeholder Awareness Raising and Confidence Building

It is also necessary to inform and educate farmers, bankers and regulators about the potential for smaller scale AD. At a recent seminar hosted by Walford College, it was clear that the appetite among farmers to get involved in AD would significantly increase, if they could access technology and operating models that were suited to farm adoption.

Possible initiatives might include:

- Working with industry bodies like WRAP and NNFCC to promote small-scale AD to farmers, regulators, planners and financiers;
- Organisation of regional events and study tours to show farmers and other rural stakeholders what AD can deliver with appropriate scale and relevant technology on farms;
- Collaboration between stakeholders and the regulatory bodies to create the framework for small and micro-scale AD on farms with minimal regulatory burden.

The RASE would also like to propose a national competition to raise awareness of farm-scale, affordable AD units that are more attractive to a greater number of farmers.

A successful competition and better information availability on the various technologies in operation will help to highlight many of the benefits that are often quoted for AD at a farm level and explored in this report and help the development of the next generation of small-scale Anaerobic Digestion plants on farms to manage slurries and generate energy.

9 Appendix A – The Low Cost AD Challenge

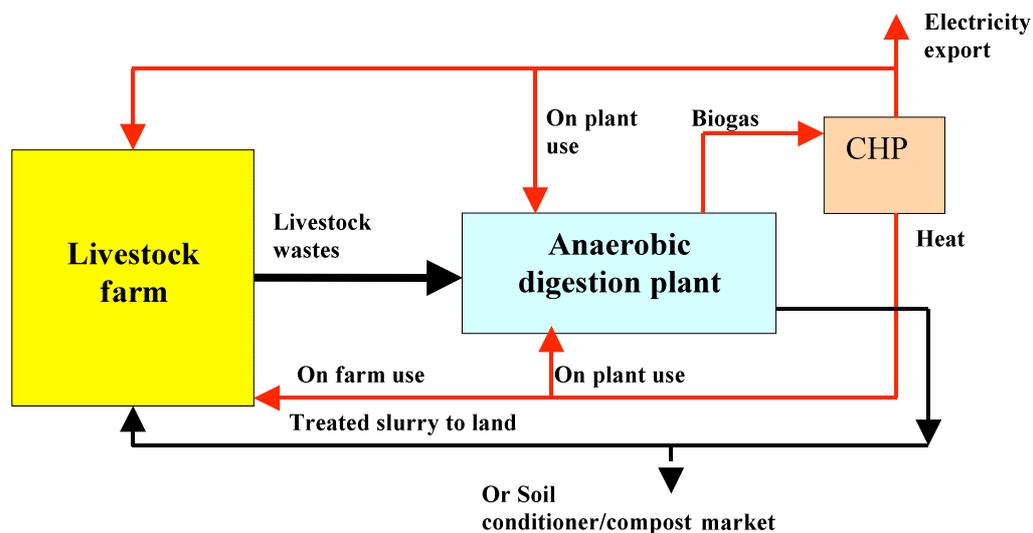
9.1 Scope for On-farm AD plants

In 2007, AEA was appointed to help DEFRA review the economics of AD plants in the UK in the light of a number of policy-based questions related to livestock waste, but also taking account of other wastes in England⁴¹. It examined the GIS Livestock Census data from 2006 and the scope for on-farm and centralised AD plants, by modifying an in-house model which was designed to facilitate research into the sensitivity of key variables, including electricity base price, ROC price, heat price, waste quantities, landfill tax & gate fees, and capital expenditure. In the model, internal rate of return (IRR) is used as an indicator of the efficiency of an investment.

In general, if the IRR is greater than the project's cost of capital, the project will add value for the investor/farmer. An IRR of 15% is considered to be good for private sector to be attracted to the AD projects. In order to arrive at the definition of low cost AD plant, information was collated based on all those with positive returns (i.e. IRR > 0%) and on which factors that improve economics were then tested. The basic schematic of the 'on-farm AD plant' concept is depicted in Figure 1.

The economics of anaerobic digestion vary according to a wide range of factors and the model was designed to be flexible, as far as possible, to understand how key factors interact and what policy support may need to be implemented to help bring AD forward to the market. The model was driven by underlying information extracted from Defra's Farming Statistics 2006 on the location and size of farms across England. It contained over 66,000 livestock farms and the analysis was based on the head of dairy and non-dairy cattle, fattening pigs, and egg laying poultry.

Figure 1: Schematic of on-farm AD plant



⁴¹ The analysis partly built on that carried out as part of the Defra study (by AEA, AC0402), completed in December 2005.

A set of runs were carried out to examine the impact of the Government's current incentives applied to AD (Feed-in-Tariff at 11.5 p/kWh electricity) but also how all year housing (AYH) of livestock and capital cost reduction (of 20% and 40%) would impact on the number of viable on-farm AD plants in England. As part of the economic sensitivity analysis, the runs were then repeated using double the electricity tariff. Table 1 lists the run details.

Table 1: Design of the on-farm AD model runs

Run	Capital cost	Feed in Tariff	Livestock housing
Run A	Current	11.5 p/kWh	Seasonal
Run B	20% reduction	11.5 p/kWh	Seasonal
Run C	40% reduction	11.5 p/kWh	Seasonal
Run A (AYH)	Current	11.5 p/kWh	All year round
Run B (AYH)	20% reduction	11.5 p/kWh	All year round
Run C (AYH)	40% reduction	11.5 p/kWh	All year round
Run D	Current	23.0 p/kWh	Seasonal
Run E	20% reduction	23.0 p/kWh	Seasonal
Run F	40% reduction	23.0 p/kWh	Seasonal
Run D (AYH)	Current	23.0 p/kWh	All year round
Run E (AYH)	20% reduction	23.0 p/kWh	All year round
Run F (AYH)	40% reduction	23.0 p/kWh	All year round

The livestock numbers for each farm were used to estimate the size of digester required and therefore the economics of that plant. Each farm scheme was then sorted according to its economic potential (IRR) and average on-farm AD plant statistics were generated for each IRR band; that for 'Run C (AYH)' is shown in Table 2. The table illustrates the number of viable AD plants with respect to IRR, the number and proportion of livestock covered by the overall solution for England as well as energy output statistics.

Table 2: Output based on Run C (AYH)

Total number	IRR (%)	Number of farms categorised by main CH4 generation stream				Proportion of England Total				Mean Generator Size (kW)	Mean Digester size (m3)	Mean Capex (£)
		Dairy	Beef	Pigs	Poultry	Dairy	Other Cattle	Pigs	Poultry			
889	0-5	608	22	222	37	10.2%	1.7%	6.1%	4.3%	19	232	£ 243,436
580	>5-10	332	8	211	29	7.6%	0.9%	7.5%	4.5%	25	283	£ 256,423
390	>10-15	123	1	239	27	3.9%	0.3%	11.2%	5.6%	32	287	£ 261,791
249	>15-20	34	5	193	17	1.6%	0.9%	11.5%	4.7%	40	306	£ 270,789
152	>20-25	10	0	128	14	0.6%	0.1%	9.8%	5.0%	50	332	£ 282,156
135	>25-30	3	0	118	14	0.4%	0.1%	11.5%	6.8%	65	410	£ 305,623
82	>30-35	0	0	67	15	0.0%	0.1%	8.3%	9.3%	82	506	£ 334,077
35	>35-40	1	0	28	6	0.1%	0.0%	4.7%	5.0%	110	696	£ 385,488
25	>40	0	0	22	3	0.0%	0.0%	4.5%	3.3%	136	809	£ 422,565
2537		1111	36	1228	162	24.4%	4.1%	75.2%	48.5%	33	296	£264,195

Table 3: Consolidated output from the 12 model runs

Model run	Total number	Number of farms		Proportion of livestock in England		Mean Generator Size (kW)
		Dairy	Pigs	Dairy	Pigs	
Run A	1128	57	926	3.5%	73.5%	56
Run B	1282	107	1019	5.2%	75.3%	52
Run C	1481	189	1127	7.4%	74.5%	43
Run A (AYH)	1672	492	1026	14.1%	77.1%	47
Run B (AYH)	2013	709	1129	18.1%	77.8%	41
Run C (AYH)	2537	1111	1228	24.4%	75.2%	33
Run D	2342	681	1445	17.8%	79.5%	34
Run E	2724	999	1502	23.0%	73.6%	30
Run F	3177	1478	1483	29.7%	61.0%	25
Run D (AYH)	4770	2930	1534	46.2%	78.3%	24
Run E (AYH)	5638	3725	1566	53.5%	71.5%	21
Run F (AYH)	6607	4692	1507	61.0%	56.1%	17

Table 3 shows the consolidated output of the runs and Figure 2 illustrates how the number of different livestock farms varied with IRR. Figure 3 shows the changes in intensive pig and dairy farms that can support viable AD plants, as a function of the 12 runs.

Figure 2: Illustration of the farms with positive return on investment (four runs are depicted)

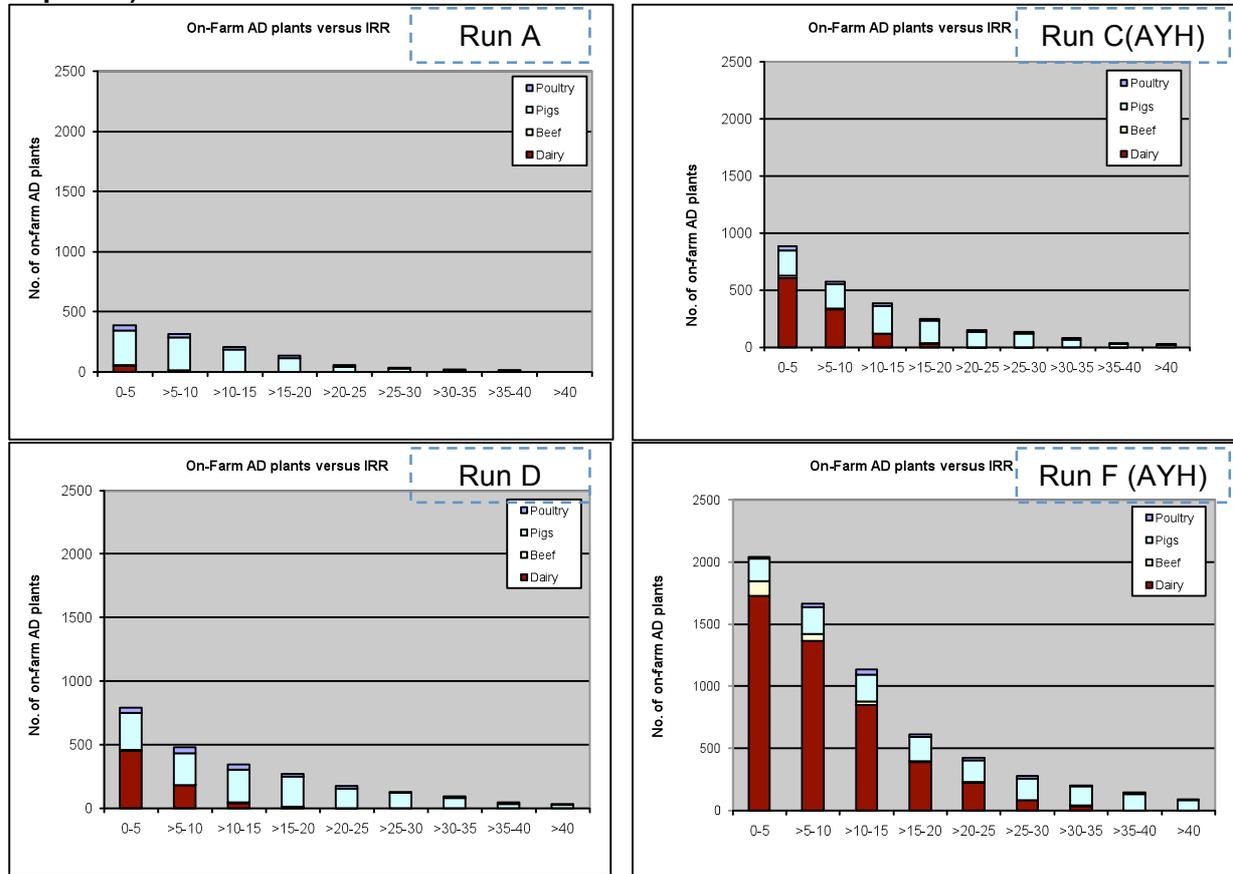
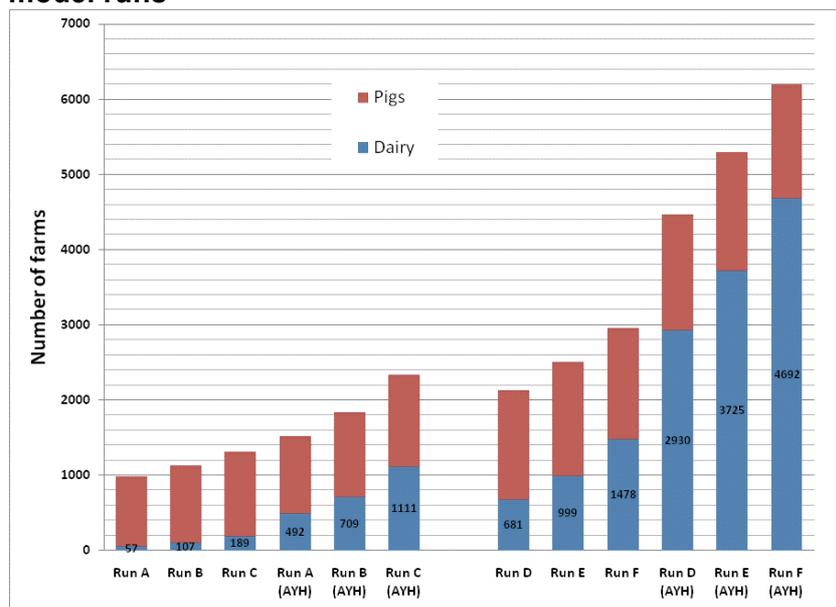


Figure 3: Illustration of number of farms with positive returns, as a function of the 12 model runs



9.2 Principal Outcome

The above results show that the greatest impact from capital cost reduction (and the focus of the challenge) should be on dairy farms. Based on the current incentives (Feed In Tariff of 11.5 p/kWh electricity), the number of dairy farms with viable AD plant increases from around 50 to 1100 with 40% reduction in capital cost and all year housing. However, if the FIT was to be doubled then the number of viable dairy farms with viable AD plants would rise to around 4700. The total number of pig and poultry farms with positive return AD plants, remains roughly the same with the above model runs (around 1000 pig farms and around 150 poultry farms).

Overall, the analysis shows that the competition for low cost AD plant should be targeted at dairy farms only. The size of dairy farm required for viable AD is much larger than the average size of dairy farms, but as the current practice shows, there are various opportunities of other feedstocks that could be added to the livestock slurry to generate 72-100 kW of biogas – the range suggested for the low-cost AD plant challenge.

Table 3 provides the range of the dairy farm and AD plant parameters that should be targeted for the low-cost AD plant competition.

Table 3: Range of the on-farm AD plant characteristics that should be targeted for the low-cost AD plant competition

Key parameters	25 kWe (72 kW biogas)	35 kWe (100 kW biogas)
Installed capacity of CHP engine	28	40
Number of dairy cattle (lower number will require other feed such as grass/maize silage)	135 - 270	190 - 380
Type of waste	Slurry	Slurry
Quantity of cattle slurry (kg/d)	14,000 - 18,000	20,000 - 26,000
Size of digester (m3)	360	500
Total capital cost, current	£270,000	£300,000
Capital cost, with 40% reduction	£160,000	£180,000
Internal rate of return	6%	11%

10 Appendix B – Case Studies

10.1 Colin Rank – Kemble Farms

Fast Facts - Kemble Farms



Digester Size:	1480m ³
Digester Type:	Mesophilic, gas mixed, insulated steel glass coated tank, fixed roof, external heat exchangers
Gas Use:	300Kw CHP, LEC's, ROC's and REGOS, extra heat used for dairy hot water and 3 on-site cottages via district heating
Commissioned:	Jul 2008, generating in Sep 08, first investigations 2005
Feedstock (T/yr):	Slurry from 750 dairy cows housed indoors year round: ~17-20,000 T/yr Maize: approx 2,500 T/yr Glycerol: approx 450 T/yr
Farm Size:	950ha + 450ha contract farmed, all in NVZ
Capital Cost:	£1.2M, part funded by 37% Bioenergy Capital Grant of £314,539, with the remaining amount funded from own resources
Issues:	Unreliability of CHP
Barriers to AD:	Regulation
Advantages:	Fantastic win-win process

In 2005, Colin Rank, Chairman of Kemble Farms, began investigating the possibility of using renewable energy, but for their particular situation, PV and wind were not viable. After a visit to German digesters early in 2006 and application for the Jan 2007 Bio-Energy Capital Grants Scheme, digester building commenced during the wet winter of 2007/8 by Greenfinch Ltd, with digester commissioning in July 08 and electricity generation commencing in September. The size of the plant was limited by Central Networks electricity export of 300Kwh from the site which is 12 km from the nearest substation. There is a possibility of being able to expand the system by running a 12KV line over fields to Scottish and Southern, but high infrastructure costs currently preclude this.

The Farm hopes to recover the capital cost in approximately 7 years. Because of several amendments to the plant, annual running costs are difficult to quantify, but are estimated to be in the region of £33,000 per annum.

Farm Type: Kemble Farms is a 950ha farm (of which 830Ha is available for digestate spreading), with further 450ha contract farmed. Wheat, barley, beans and oilseed rape is grown, along with 55ha energy maize, 145 ha forage maize and 40ha of grass leys. All land is in an NVZ.

The farm's herd of 750 dairy cows is generally housed indoors year round, especially when in prime milk. Colin Rank, Chairman of Kemble Farms, points to a recent study which debunks the popular theory that cows prefer to be outdoors eating grass, which may be insufficient for their needs at times. This research clearly supported his view and demonstrated that, given the choice, cows prefer the housing configuration at Kemble Farms and that the industry needs to do a PR job to get this message across.

All housed cows are bedded on sawdust, with beds being refreshed at every milking and all this goes into the digester. Transition cows, hospitalised animals, cows with some sort of cubicle averseness and young stock are bedded on straw which is not put into the digester, but is composted before being incorporated into fields.

The farm has an excellent website at: <http://kemblefarms.co.uk/?cat=3>

Digester Description: The digester is fed using a fixed tub mixer feeding through a Borger feeder against a non-return plug. The pressure in the secondary circuit into which solids are injected is regulated by two pumps acting in tandem either side of the Borger in order to keep the pressure low. There was an initial problem with loss of plug in the Borger, but this was cured by the use of an extra pump which took off the pressure. All feed is then processed through a macerator before going into the digester.

The digester tank is a single insulated steel glass coated circular tank, approximately 13m across and 12m high. The tank is gas mixed using three 18-port rotary valve 'skids', with mixing pipes distributed across the conical floor of the digester. The plant happily runs on 2 skids.

Gas is stored in a flexible gas dome.

The digester is mesophilic, heated with an external heat exchanger. Heat is provided by the CHP or by a stand alone biogas boiler. The retention time is around 30 days.

Parasitic load is 5.3%

Digestate Use: Output from the digester is separated using a Sepcom Bio 65. Separation is used for ease of handling and in order to reduce volumes which need to be stored under NVZ rules. The separated liquor is returned to an intermediate tank by gravity, then pumped to one of two holding tanks of around 3000T each.

20,000m³ of digestate is produced per annum. The separated fibre is returned to the land as a soil conditioner between crops. The liquid fraction is used as a plant fertiliser both in crop and between crops, being spread by tanker or lay flat pipe to injector or trailing shoe.

N, P and K minerals supplemented as required.

Kemble Farms is looking to explore other avenues with separated fibre (eg selling to the public) in the future once the RHI has been published. They are conscious that it is a valuable source of organic matter which should be ideally returned to their land. However, if they were importing wastes, there might be an opportunity to export the fibre under the PAS110 protocol.

Whilst no trials on the digester have been carried out by Kemble Farms, Colin Rank makes the following very pertinent observation “The main benefit of the Digestate is to provide a recyclable source of both N and also of organic material for soil conditioning. Many minerals and trace elements are fed to the cows which pass through the cows and are returned to the land where they are taken up by the plants grown on them. The availability to both animal and human absorption is greatly increased. Minerals and trace elements are not readily absorbed directly but are readily taken up by plants. Eating the vegetable matter grown on ground rich in trace elements and minerals results in a high absorption of the minerals in the plants. The farm based Biogas system preserves that important cycle of the mixed farm and is a benefit far more valuable to the population than food grown organically.”

Gas Use: Biogas, composed of 65%-68% methane is used through a 300kWe CHP, which also produces around 385 kWth. The CHP is based on a Perkins engine with Cogenco controls and housing. The heat is partly used to heat the digester and other components such as the glycerol tank and the rest is used to preheat hot water in the dairy and in three cottages on site. More than 200kWth is discharged to atmosphere.

LEC's, ROC's and REGOS are claimed.

Issues with the Installation: The system has suffered from a poor record on reliability of the CHP. The engine needs a pre-lubrication system to permit continuity of lubrication through, in particular, the turbo, in the event of a dead stop. The controls are over-complicated, resulting in frequent false alarm stops, so the running target of 80% utilisation has not yet been achieved. The farm is slowly putting in place the requisite modifications to improve utilisation, but Colin feels that this is not something that they should have to be doing.

Legislation, Licensing and Regulation: The farm has a bespoke Environmental Permit which permits the use of glycerol. However, the Environment Agency is still trying to decide if the farm is permitted to use glycerol from the production of biodiesel when the feedstock is technically a waste. Kemble Farms currently finds itself in the position of trying to

demonstrate that the end of waste tests are met and that they do not need PAS 110 to spread the resulting digestate on their fields.

Record Keeping: Maintenance, which is done by the farm, Marches Biogas or Cogenco as appropriate, is recorded separately from the day-to-day running of the plant. All plant activities are recorded and a system upgrade is soon to be installed which will allow automatic data recording and analysis.

Soil analysis is carried out independently as part of the farm's normal arable activity.

Training: The installer carried out initial training, but there has been ongoing on-the-job training, as well as experiential training in manning the plant. As part of the Environmental Permitting, it was necessary to carry out WAMITAB training.

Advantages of the Digester: Colin comments, 'It's a fantastic win-win process. I have yet to see a down side from a process point of view. We plan to get bigger, but I am not sorry we started at a modest output. We already advise others on the finer points but we would like to see the process truly freed up as a farming tool.'

Barriers to on-farm AD: Regulation. Colin's arguments are cogent and succinct:

'It [regulation] must be simplified to allow flexibility and a wider use of farm ingredients. We are allowed to feed products to the cows that are not allowed to be fed to the digester.

In truth, the digester is simply another stomach; we think of it and run it as a 'tin cow'. The EA in particular seem to have been particularly slow in getting themselves educated into what AD can do for the environment and how we can make the most of it. Their concern is almost 100% waste regulations from an entirely legal point of view and the legality of waste permitting has grown into an uncontrollable monster!

Other regulating bodies such as OFGEM have become more user friendly of late and using companies who regularly deal with these agencies is a must.

Connection to the grid is an unwelcome uphill battle but, once done, it can be forgotten. FITS make admin much easier and improve cash flow significantly.

For the larger farms a change in the thresholds for Environmental Permit Exemption needs to be revisited. There was an attempt by the EA to link AD with composting. For 1000 tonnes of compost to be windrowed out in the open is clearly a sensible threshold for that industry, but it simply does not translate into the size of a digester in AD. The bigger the digester, the better! Also for there to be a threshold of thermal inputs in the combustion of wood burning systems of 0.4kW is sensible, but again it simply does not translate into AD. The two thresholds bear no relationship to one another in the AD model.

"Wehad to go through the process of obtaining a bespoke permit costing around £20,000.

Unnecessary in the extreme."

The EA were advised by nearly everyone to adopt a similar position that OFGEM had taken in regard to maximum output of 3 megawatt. They ignored all the experts and went ahead making a small uplift in the size of digester to 1250 tonnes with the present exemption levels. This should be revisited if AD is to be a viable on-farm process. Bespoke Permitting is extremely expensive. The standard permits forbid the digester to be within 250 metres of a borehole. No dairy farmer would normally drop a borehole a long way from his dairy for obvious reasons. The siting of the digester also needs to be as close as possible. So very few mixed farms qualify for a standard permit. We failed on that point and had to go through the process of obtaining a bespoke permit costing around £20,000.

Unnecessary in the extreme.'

10.2 Stephen Temple – Copys Green Farm

Fast Facts - Copys Green Farm



Digester Size:	870m ³
Digester Type:	Mesophilic, gas mixed, insulated steel glass coated tank, fixed roof, external heat exchangers
Gas Use:	140kW CHP, FITs, extra heat used for grain drying, cheese making, dairy hot water and heating the house.
Commissioned:	2009
Feedstock (T/yr):	Slurry from 100 Holstein and Brown Swiss dairy cows: approx 2,500 T/yr Maize Silage or fodder beet: approx 2,500 T/yr Whey from cheese making will be approx 210 T/yr (not used yet)
Farm Size:	230ha, arable and dairy, all in NVZ
Capital Cost:	Approx £750,000, self financed, with £100,000 capital grant having to be turned down
Issues:	Unreliability of CHP. Technology provider bought out part way through project
Barriers to AD:	Administrative: EA and OFGEM paperwork
Advantages:	Recycling and improved utilisation of crop nutrients. Using manures and second quality silage; utilising heat available

Copys Farm owners Stephen and Catherine Temple have carried out a wide range of measures to help ensure the sustainability of their enterprise and the anaerobic digester is just the latest of these. They firmly believe in 'leaving the land and the farm in a better state than you found it'⁴² and practise this philosophy in a number of ways. These include using carbon neutral fuel wherever possible (their house is heated using a woodchip/spoiled grain biomass boiler), driving highly energy efficient cars, using low-energy bulbs throughout the farm and carefully monitoring farm vehicle fuel usage. They have won a number of awards, including the Farmers Weekly Green Energy Farmer of the Year 2010.

Stephen Temple's interest in AD was sparked when he played a small part in a team which built a plant in the 1970s in Malawi.⁴³

The plant was designed and constructed by Greenfinch which merged with Biogen partway through the project in late 2008, and was commissioned in 2009.

The capex of approximately £750K was completely self-financed, as a £100,000 Bioenergy capital grant which was awarded had to be turned down when it became clear that it would have stopped double ROCs/FIT payments. Estimated payback period is 8 years and estimated running costs are approximately £83,000/year, with the largest element of this being the feedstock.

Farm Type: Copys Farm is a mixed arable and dairy farm of approximately 230ha. The majority of the land is owned, with a few meadows rented from Holkham Estate. The main enterprise is dairy, with approximately 100 cows, plus a similar number of young stock, predominantly pedigree Holsteins, with a small proportion of mainly pedigree Brown Swiss. The Holsteins have been averaging about 11,500 litres of milk a year.

Arable crops include spring and winter barley, maize fodder, fodder beet and spring beans. The farm now grows four times as much maize as they used to, in order to feed the digester—currently nearly 55ha.

One way in which the farm may be able to save fuel and improve their land husbandry is to use strip tillage for maize growing. This season, they are trialling a machine for this, which has been imported from France.

Other farm enterprises include:

- Cheese making – which uses about 25% of the milk produced and produces 25T/yr of cheese
- Haulage – carting sugar beet and grain
- Farm contract work
- Electronics for farmers

⁴² [<http://unaverse88.wordpress.com/2010/01/>]

⁴³ [[http://www.afmp.co.uk/appl/GB/GB145FAR/gb145cfg.nsf/b8e0504b45746174c1256d1700341133/4db03e7eb5842c63c12577a80052f5f4/\\$FILE/Autumn_WS_Final.pdf](http://www.afmp.co.uk/appl/GB/GB145FAR/gb145cfg.nsf/b8e0504b45746174c1256d1700341133/4db03e7eb5842c63c12577a80052f5f4/$FILE/Autumn_WS_Final.pdf)]

Digester Description:

The digester is fed via a feed hopper and mixer and substrate is pumped into the digester via a macerator.

The digester tank is a single insulated steel glass coated circular tank, 10m in diameter and 10m high. Insulation is 100mm Rockwool. The digester is mixed using two 18 port skids and contents are heated to 37°C-40°C via an external shell and tube heat exchanger. The 36 gas mixing pipes are distributed on the conical digester floor.

Gas is stored in an external 350m³ flexible gas bag. Hydrogen sulphide scrubbing is carried out by air injection into the gas mixing.

Retention time is between 40-50 days.

The digester consumption is logged, with the parasitic load being approximately 36kW/tonne fed.

Digestate Use: Digestate is separated using a rotary screen press, with the solid fraction being stored, then spread by muck spreader, cultivated or ploughed in. The liquid fraction is stored in a lined lagoon (5 months' storage), then pumped through the irrigation system.

The Temples consider the digestate to be too valuable on the farm for it to be sold.

150ha are available for liquor spreading, with an additional 60ha available for the spreading of solids. Nitrogen is supplemented according to crop needs, with P, K and Mg supplemented, depending upon soil analysis.

Gas Use: Biogas, produced at the rate of about 70m³/hr, is used in a 140kW CHP, with 131kVA being exported to grid. The heat is used for cheese making, dairy hot water, grain (and possibly green crop) drying and heating the house. There is also the possibility of using district heating pipe to heat cottages across the road.

The installation attracts FITs at the 20 year guaranteed rate of 11.5p/kWh, plus an additional 3.5p/kWh secured on the open market.

Issues with the Installation: There have been a number of problems with the CHP, which is due to be replaced by a 170kW unit. The only other problem is due to flints in the feedstock, which damage pump rotors.

Legislation, Licensing and Regulation: Changes in the Environment Agency requirements during the project caused problems. In the initial project stages, there were no permitting requirements, then Paragraph 12 Exemption (Storage and Composting of Biodegradable Waste) came into force and next year Standard Rules will apply.

Additionally, a Paragraph 7 Exemption (Waste for the Benefit of Land) was needed for the initial seeding of the digester from Anglian Water's digester.

There were problems with getting an update on the import MPAN for a half-hourly meter.

There were a number of problems with OFGEM registration for FITs – the system was not set up for farm-based AD. Other issues are covered below under 'Barriers'.

Record Keeping: The following is recorded:

- Daily feed volumes and type
- Monthly operating hours for each item of plant
- Monthly parasitic power consumption
- Monthly electricity generation and export
- Monthly gas consumption

There is also continuous data logging of gas quality, gas holder level, temperatures, hopper levels, motor currents on the macerator and power feeder and the level of the digester.

A daily diary is also kept which records any problems and maintenance.

Training: Training was given from the commissioning engineer during commissioning of the plant.

Advantages of the Digester: With his philosophy of minimising waste, Stephen Temple believes that the value of the digester lies in being able to utilise second quality silage and cattle manures to create energy and to use most of the heat available. He is also impressed with how well the digestate liquor works on grassland.

Barriers to on-farm AD: The biggest barriers are administrative and include the Environment Agency and OFGEM paperwork. At this scale, Stephen feels that the paperwork is disproportionate to the risk.

Speaking to the Arla Foods Milk Partnership in their Autumn 2010 bulletin “The White Stuff”, Stephen Temple pointed out that his motivation in installing the digester was to ensure the slurry was *less* polluting, so was bemused when he found that when he tried to install the digester, the worse the regulations became and the more the Environment Agency got involved. He comments, ‘The government is allegedly encouraging farmers to install renewable energy plants and benefit from feed-in tariffs, but the bureaucracy has been horrendous... It’s all to do with how waste is classified in the UK and it’s been very difficult because, yet again, we look at it very differently than other EU countries. Unbelievably, it seems that the ones to help you through the process, such as the Environment Agency and Ofgem, are against you at a time that you need most support. A lot more joined-up thinking will have to happen if farmers are really going to embrace this technology at the speed that the government wants to hit its CO2 targets.’

“The government is allegedly encouraging farmers to install renewable energy plants and benefit from feed-in tariffs, but the bureaucracy has been horrendous”

As with many digester operators, Copys Farm has considered glycerol as a possible feedstock, but encountered another set of issues ‘...the Environment Agency classify glycerol, a by-product of biodiesel manufacture a waste, although to use it in an anaerobic digester we would have to purchase it. We could buy exactly the same material from Holland, not classified as waste but produced in exactly the same way under the same EU regulations. The EA are now threatening to reclassify the material as waste when brought

into the UK, making a mockery of the EU “Level playing field”. This is only one example of unnecessary EA gold plating of EU regulations, there are many more which need to be sorted out. It seems that anything they fancy classifying as a waste gets so categorised, whether it is genuinely a waste, a valuable by-product, or even the main product of a process (in some cases they classify biogas as a waste).’

10.3 Trevor Lea – Hill Farm

Fast Facts - Hill Farm



Hill Farm digester with control kiosk in foreground, loading pit on right, with loading auger behind, digester behind kiosk, elevated separator in the background and second digester on the right hand side in the background.

Digester Size:	105m ³
Digester Type:	Mesophilic, gas mixed, 50mm PU insulated GRP, FGB Style
Gas Use:	Farmhouse cooking and heating; farmhouse and dairy hot water
Commissioned:	1989
Feedstock:	Slurry from 80 dairy cows housed indoors from Oct-Apr ~4T/day
Farm Size:	80ha organic farmed, not in NVZ
Capital Cost:	£50,000, with 50% grant under Farm Pollution Abatement Scheme
Issues:	None
Barriers to AD:	Not being able to digest organic substrates from outside the farm
Advantages:	Value of digestate; ease and simplicity of slurry management

Hill Farm is a small organic dairy farm on the Welsh/Shropshire border and is a shining example of how the technology can be integrated onto a farm at this scale. Trevor Lea has had his digester for more than 20 years and would heartily recommend AD to farmers, particularly because of the wonderful effects of the digestate on the land.

In 1989, there was the threat of a lot of new regulations regarding slurry storage and handling, so he investigated a number of options and became interested in anaerobic digestion. Farmgas (and, subsequently, A J Murcott) supplied and installed the digester, since the cost was comparable to putting up a slurry store. For 20 years, Hill Farm has enjoyed thousands of pounds of savings in energy and fertiliser bills. The 80 ha farm is managed solely by Trevor and his son Lincoln, so everything needs to be reliable, simple and easy to manage. The digester has been very well integrated into the heart of the farmyard and is monitored by “glancing into the farmyard to ensure that all the lights are green and that the separator is running”. The Leas treat the digester like a ‘legless animal’ and look after it like one of the animals on the farm, ‘keeping it warm, fed and emptied’!

The farm has been fully organic since 2001, which was a relatively easy transition, as he had not bought any nitrogen fertiliser for over 20 years. Trevor believes that his cows are healthier on the organic regime.

The payback period for the digester was less than 4 years. Trevor and his son do most of the maintenance, but he estimates that annual running costs are less than £1000 per year.

In 1995, the opportunity arose to purchase a second digester of 145m³, again with a 50% grant, and the Leas installed the digester themselves. This is currently used for storage, but has been designed so that it could easily be brought into production at any time when extra substrates can be brought onto the farm.

Farm Type: Hill Farm is an 80ha organic dairy farm on heavy clay. Their herd of 80 Friesian cows are kept in from October to April and bedded on chopped straw on top of a clay bed. Crops include whole crop wheat and peas.

Digester Description: Slurry is scraped directly into a reception pit with a grate on the top and then pumped directly into the digester with a standard tractor driven Landia chopper pump. Any material which does not go through the slats is scooped into a separate loading pit and augered directly into the digester. In order to minimise wear on the equipment, they try to minimise long straw and stones from hooves/grit getting into the digester (eg from the loose housed yards) and this relatively small amount of material is simply composted. Waste grass also goes into the digester. Dairy washings are not put into the digester and Trevor notes that these smell much more than the separated liquid fraction from the digester.

The digester itself, a well proven Farmgas ‘B’ model (FGB), is largely buried and constructed from 50mm PU insulation sandwiched with GRP on a concrete base. Gas mixing is carried out with a Waste Refineries 36 port rotary valve which replaced the original Farmgas 12 port one.

Gas is stored in a .75m³ bell over water insulated GRP gas holder.

The digester is mesophilic, heated to 38°C with internal heat exchangers, using heat provided from a biogas boiler. Retention time is between 24-28 days.

As the digester is fed, the output overflows into a 150mm sewage pipe arrangement in a small pit which is channelled into a nearby larger pit under the separator. Digestate is currently pumped up to the separator using the tractor.

During summer, there is less feedstock, as the cows are only in twice a day when being milked. Waste grass, e.g. from trimmings and toppings, is used to feed the digester, along with the slurry. Although gas production goes down, Trevor believes that because the feedstock is warmer (and rich because of the good grazing), it does not have to be heated as much and produces very good gas. When the cattle come in for winter, short term extra heat for the slurry is provided by a diesel boiler which had been scrapped by a neighbour and reconditioned by the Leas. Lincoln has discussed plans to possibly supplement digester heating using thermal solar.

The farm is on single-phase electricity so it is easier to use gas directly.

Digestate Use: Output from the digester is separated using an elevated Carrier drum press separator.

Because the farm is on heavy clay, the liquid is put into a soil based lagoon and spread with an umbilical cord (designed and built by the Leas) and tanker throughout the growing season. The fibre is spread in spring using a conventional muck spreader. Because they have been using the digestate for so long, Trevor and Lincoln are aware of its effect on the land and simply use it 'where it is needed'. For the first time this year, they have bought some organic mineral fertiliser made from ground rock which contains, amongst other things, Na. They plan to use that, to see what effect it has on crop production.

Before he went organic, Trevor sold fibre off the farm. The local gardening club very soon learned to come back for more each year, as they kept picking up prizes for their produce which included tomatoes and sweet peas. However, he discontinued the sales because he couldn't compete in price with cheap Local Authority and garden centre-produced compost and because, having gone organic, he could no longer bring in other organic matter and the digestate was therefore more valuable on the farm.

Mrs Lea is also a keen gardener and the farm flowerbeds and garden are very impressive.

Gas Use: At maximum output, the digester produces around 100m³ of biogas per day. Gas is used to heat the digester. The bulk of the gas is piped to the house where it runs a Rayburn with a back boiler, so that it provides cooking, heating for the house and hot water for both the house and dairy. When necessary, top up heat for the dairy water is provided using cheap overnight electricity. The house does have a back up cooker and heating, which have been used only very rarely over the years.

Issues with the Installation: The digester was originally seeded using very watery sewage waste, but it didn't mix well with the slurry and the long fibre straw formed a mat on the surface, so the commissioning time took around two months.

The digester has only been shut down twice since it was installed and it has been emptied once.

Recently, the tractor was being used to pump digestate to the separator, but this has now been replaced with an electric pump, as diesel was getting expensive and the process was time-consuming.

Legislation, Licensing and Regulation: When this digester was built, the only criteria necessary was to comply with the Pollution Abatement Grant conditions. The grants were simple for the farmer himself to apply for and were awarded to anyone who could demonstrate that they achieved a certain length of slurry storage time. The grant ceiling was 50% of £85,000. Planning was not necessary.

Record Keeping: The farm carries out regular soil analysis as part of its normal arable practice. No other record keeping on the digester is done. The simple control panel has easily visible green, orange and red lights. Lights are checked to ensure they are green. Maintenance is usually carried out by the Lea's, as it is equipment they have experience with, such as pumps and augers.

Training: Training has been largely experiential.

Advantages of the Digester:

For the Leas, the main advantage of the digester lies in its simplicity, 'We use the gas to keep us warm in the house and the digestate to nourish the land.'

He feels that the digester is robust, cost effective and easy to use, fitting in well to both his farm and his farming practices. 'It is built into the farmyard and we can keep a close eye on it, just like one of the animals.'

Because of years of experience with digestate, Trevor's real world observations are most fascinating and nearly unique in this country.

He makes the following points:

- the liquid fraction has a noticeable and almost immediate effect on plants because the leaves, even clover, turn a darker green
- the fibre is applied to pasture and quickly disappears. It is 'lovely to see' how well it simply disintegrates into the soil and doesn't get into the next crop and picked up by machinery. The solids can be spread on any field without any problem because it is so well digested.
- faster re-grazing: after spreading of the fibre, cows are happy to be put out 2-3 weeks later with no problems.
- when the digester was installed, they noticed immediately that it encouraged valuable nitrogen-fixing clover in the leys
- the heat of the digester kills most weed seeds, which is very useful on an organic regime. However, clover seeds survive – a further benefit.

"We use the gas to keep us warm in the house and the digestate to nourish the land."

- in fertiliser value terms, 4,550 litres of separated liquid provides around 30 units nitrogen, 40 units of potash and 12 units of phosphate.

- Trevor notes that regulation appears to be trying to push farmers to inject slurries and that the regulators do not appear to understand that digestate does not behave like slurry. He observes the number of dead worms appearing on the top of a field which has been injected with slurry, but he does not have that problem with his liquid digestate spread by umbilical cord. His soil looks incredibly healthy and is full of worms.

Barriers to on-farm AD: Because of the age of his digester, Trevor Lea has not encountered some of the hurdles that other interviewees have, although he would like to be able to digest organic substrates from other farms without any problem.

10.4 Wyn Evans – Caerfai Farm

Fast Facts - Caerfai Farm



Digester shed showing thermal solar installation on top and (inset) beautiful Caerfai Bay

Digester Size:	70m ³
Digester Type:	Insulated underground concrete tank with 12 port gas mixing.
Gas Use:	Anywhere needed: usually digester and Aga with back boiler, but also extra small gas boiler and dairy washings.
Commissioned:	First digester 1977, second digester 1978, current digester 1979
Feedstock:	Slurry from 65 cows housed between Nov/Dec and mid-March. Currently bedded on sawdust. Also whey from cheese making, approximately 43000 l/year.
Farm Size:	Digestate spread on approx 55ha; another 2.5ha potatoes.
Capital Cost:	£6,500 plus shed (Shed build in 2008: £8,000-£10,000)
Issues:	Originally, problems with sealing concrete tank. Now, none to speak of.
Barriers to AD:	Lack of confidence and fear of the unknown: people think it is so complicated, but it is really very simple.
Advantages:	Smell reduction, less taint, the way digestate works so well on crops, the simplicity of the system

With solar PV, extensive thermal solar, ground source heat, a wind turbine and a 32 year old anaerobic digester, there is not much that Wyn Evans does not know about real-life running of renewable technologies and his farm is a living example of how these various technologies can be used to reduce the carbon footprint of farming. It is therefore somewhat ironic that he failed to qualify for a now-defunct government-run agri-environmental scheme for a number of reasons, including the fact that his hedgerow-bordered fields were too small to have a 6m set-aside margin and regulators did not understand that digestate which is plate spread does not have the environmental problems of slurry—the scheme gave qualifying points to farmers who inject slurries.

As an organic farmer for 20 years, Wyn Evans knows the value of recycling nutrients to land and believes that worms are a sign of healthy soil. He points to farms where slurry spreading is evident because of the smell and because of the flocks of birds picking up worms where they have come to the surface of the soil. This is because slurry has a high BOD and deprives the soil of oxygen, forcing worms to the surface so they do not suffocate underground. Digestate does not have such an effect.

Caerfai Farm's digester is simple and well integrated into the heart of the farmyard and the various renewable energy sources used on the farm. The farm is a wonderful showcase for renewable technologies and the Evans' believe that the secret of their success with renewables is to not rely on a single technology. In addition to the digester, the farm has a 20kW wind turbine (which produces about 15kW), a ground source heat pump, solar thermal installations on each of the houses and the digester and a recent 9.6kW solar PV installation which exceeded its projected 7800kW per annum output in the first 10 months of operation.

Wyn Evans became aware of anaerobic digestion through an enlightened teacher at primary school, but it wasn't until he heard about the technology on Farming Today that he considered having one. In 1977, he approached Farmgas, who sold him a 1.5m³ digester and gas holder for £2,200. In the following year, he bought an 11m³ Farmgas digester and produced good gas. In 1979, he decided to build a farm scale digester, again with Farmgas. However, when Farmgas pulled out, he bought some contemporary books on AD and decided to build his own.

Farm Type: Caerfai Farm is an organic dairy farm, situated on the stunningly beautiful Caerfai Bay within the Pembrokeshire Coast National Park. The site has two main farm cottages, another small farm cottage, some holiday cottages, a farm shop, a small organic cheese making enterprise and a caravan site. Organic potatoes are grown on 2.2 to 2.6 ha and around 55 ha are used for grazing and glass silage.

The bungalow on the farm uses a ground source heat pump with electricity from PV or wind turbine, solar thermal for hot water (from about Mar-Oct), a log burner and occasional immersion heater. There is an oil boiler but this wasn't even necessary in the recent cold snap. The main farmhouse uses an aga with a back boiler running on biogas, an optional small biogas heating, solar thermal and a ground source heat pump. A third small cottage uses the renewable electrics. Ground source, solar PV, solar thermal, wind and biogas are used for cheese making. Water for the campsite showers is heated with renewables.

The herd of 65 cows used to be bedded on straw, but with increasing straw prices are now bedded on sawdust. The farm is not in an NVZ. The farm originally started out using a cubicle system, then converted to loose boxes and has now converted the cattle shed back to a cubicle system and is shortly to install an automatic milking system. Cows are normally indoors Nov/Dec to half of March (about 4.5 months) and are fed on grass silage, rolled oats and 20% bought in organic nut.

Digester Description: Automatic scrapers (powered by renewable electricity) scrape slurry directly into slats at the end of the covered cow shed. Twice a day, slurry is pumped over the wall into a holding tank and flows straight into the digester by opening a normal tanker valve. Slurry was originally scraped straight off the yard up a ramp and into the digester twice a day, but with the purchase of a skid-steer, pushing slurry up the incline became difficult, so the current loading system was devised. Some dairy washings also go into the digester. About 1.5 times a week, 500-600l of whey from the cheese making enterprise is also fed into the digester, causing a significant increase in gas production within 2 hours, lasting around 24 hours. He had used glycerol many years ago and calls it 'rocket fuel' for digesters, greatly increasing the gas yield. He was recently offered the opportunity to put glycerol into the digester from a local company. However, he had to refuse, since the high cost of waste licence (£2000 or more) and the difficulty of filling in all the paperwork means that it is too difficult and expensive to use now. The local company is now apparently shipping all the glycerol to Poland where it is burnt in power stations because there aren't those restrictions there. Other organic materials are fed into the digester depending upon availability.

Output from the digester is gravity fed directly into the lagoon.

There is no digester control panel. Gas mixing is done on a simple timer. The thermal solar heating circuit has a flow and return temperature readout.

The digester was designed for 70 cows and is an insulated rectangular concrete tank 2.4m deep and about 3 times as long as it is wide. The tank was originally insulated with 2" polystyrene under the floor, on the outside of the walls and the underside of the concrete roof. It was then refurbished with 3" PU foam spray on the walls and roof and lined with glass fibre.

In 1979, as gas mixing was still in its infancy, Wyn designed a unique mechanically mixed paddle system run by a windmill. However, he found that string, straw and plastic would get wrapped around the shaft of the mechanical mixing and it did not keep the silt in suspension as well as gas mixing, requiring the digester to be emptied of silt about every 3 years. Blades on the windmill also proved to be problematic, so after 6-8 years of mechanically mixing the digester, he decided to purchase a rotary valve gas mixing system designed by James Murcott and has used that since. He has not been into the digester for over a decade now, but says that de-silting it is not a problem with a tanker and is about a half day's work.

Digester heating is done with one large and one medium sized heat exchanger. In keeping with his principle of not relying on a single renewable, he runs the larger one off biogas, oil or ground source, with the smaller one running off solar thermal. On this particular cold winter's day, the thermal solar input to the digester was running at 45°C, with the return circuit at about 28°C. He has also heated the digester with propane, coal, waste heat from an engine generating electricity and electricity from the wind turbine and PV panels.

A number of years ago, the enterprising Mr Evans tried to generate electricity by running an alternator off a diesel/biogas engine, but a fluctuating power supply in the house did not make him popular and he abandoned this after a few months.

The 2000 gallon second digester tank was pressed into service as a heat recovery unit, originally run by a compressor fridge pump which took heat out of the water and put it into the digester, with the chilled water in turn being used to cool milk. When that pump broke down after 4 years, it was replaced with one running on Economy 7 and renewable electricity from the wind turbine. Instead of pumping chilled water back towards the dairy for cooling, it is now done the other way round, pumping warm water over from the dairy and recovering heat for use in the digester.

Gas is stored in a 30m³ bell over water gas holder created by using a standard rotor moulded water tank modified to fit inside a standard concrete tank.

The digester is mesophilic, and is run at around 30°C (maximum of 33-34 degrees), with a retention time of about 21 days.

Wyn Evans prefers to minimise the use of pumps associated with the digester, because of the parasitic load, maintenance, cost and potential for blockages. Thus, the main cost of running this digester is the gas mixing pump, which uses about 12 kW per day or approximately £30/month—however, this is done on renewables. Additionally, the pump is a standard milking parlour pump, so in the rare case of failure, he is able to easily swap it with the one in the milking parlour.

Digestate Use: Digestate was originally separated, but now goes straight into the lagoon. It can be pumped out to an underground irrigation system using electricity from the wind turbine or, more usually, it is spread using a slurry tanker at the beginning of the year. It is used on 120-130 acres grass silage and grazing land. The digestate is also used to grow tomatoes in a poly tunnel.

Thirty years ago, ADAS carried out trials, concluding that the digestion process altered the nitrates, meaning that there was less likelihood of leaching; AD also significantly alters the BOD.

The Evans' reckon that they don't do enough soil sampling, but know that with organic you always get a low index on P and K; however, they believe the organic crops seem to pull out the extra nutrients from within the soil and are happy with their crop yields.

Ever the experimenter, during a particularly wet silage year, Wyn captured the silage runoff and fed it to the digester in relatively small quantities. As it was June, the cows were out and the digester was running at ambient temperature. Within a week, he was producing sufficient burnable gas to heat the digester and run the Aga.

Gas Use: In addition to being able to heat the digester, gas is mainly used to run the Aga with a back boiler, heating one of the farm cottages. It is also used in a small gas boiler for space heating, as well as heating dairy washings and cheese making. As part of the cheese making facility upgrade, he has just purchased new 750l storage cylinder which can heat water using up to 4 different sources: biogas, electric (PV), ground source and thermal solar.

Issues with the Installation: When he first built the digester, Mr Evans found that the concrete lid did not fit perfectly onto the concrete tank and leaked gas in a few places; however, this has been solved using a number of methods, including lining of the tanks with insulation and GRP. The gas mixing system also solved the problems with regular silting up of the digester.

Legislation, Licensing and Regulation: In trying to use renewables, the Evans' have found that policy on paper is to encourage renewable energy technologies, but not in reality. Whilst the digester was built with no problem before current restrictions, recent installations have been much more problematic. For example, planning for the wind turbine was originally turned down. Upon appeal, it was approved, but at a much lower height which means that it not only looks out of proportion, its electrical output has been reduced.

Record Keeping: Wyn Evans does not see a need to keep records on the digester, although he keeps records for the wind turbine because of the problems with it. The cows produce a certain amount of slurry which is simply fed into the digester. Gas mixing is on a simple timer. Wyn occasionally feels the temperature of the digestate as it comes out of the digester and/or touches the outgoing and incoming pipes from the heating circuit. If pushed, he reckons that one or two temperature probes in the digester, as well as flow and return temperatures on the heat source run by a £60 Pactrol controller would be sufficient monitoring. A simple or laser hand held thermometer could be used to measure output digestate temperature.

He regards the digester as keeping another animal in the place – you just observe that it is loaded and there is slurry coming into lagoon (i.e. passing through). Smell it or stick a hand in to see if it is warm.

Training: Training has been experiential, although Wyn notes that the most difficult part of his experience with renewables has been in building up a network of parts suppliers and people you can trust should a technical problem be encountered.

Advantages of the Digester: Smell reduction. The best thing about the digestate is that it works more quickly than slurry and has far less taint. Also, it's nice to be running the Aga on the biogas and not paying for fossil fuels.

Barriers to on-farm AD: Biggest barrier to somebody installing a digester would be the fear of going into the unknown and a lack of confidence. He says, "Everybody thinks it is so complicated because whenever you read it in the farming press it always sounds so complex and it is such a simple system. The problems are no different from any dairy farm handling slurry – either pushing it with a yard scraper or pumping it – i.e. physically handling the stuff. But this is what dairy farmers are used to."

"Everybody thinks it is so complicated because whenever you read it in the farming press it always sounds so complex and it is such a simple system. The problems are no different from any dairy farm handling slurry."

He definitely does not agree that digesters at this scale are not economic: he feels that his current digester configuration could be replicated for about £30,000 and work better.

His advice to farmers considering a digester:

- Keep rainwater kept out of the slurry.
- Buildings are covered and slurry is regularly scraped in, so that it goes into the digester cool, but no lower than 10-12 i.e. 50F to 95C. This way, the amount of extra heat needed to bring it up to temperature is reduced.
- Spend as much as you can afford on insulation. Really insulate it.
- Definitely include the thermal solar to top up the heat. Ensure digester runs east/west and have a lean-to for thermal solar. If you have a dairy farm, in summer there will be too much heat for the digester and heat can then be used for pre-heating dairy water. In autumn preparation for cows coming in, huge amounts of fossil fuels can be saved by using solar thermal: he can easily achieve 27-28°C before having to burn gas or put the heat pump in. This also means that the Aga, which used to be used from Oct-Apr, can now be used for 11-11.5 months of the year and there is still extra gas in the summer. The digester can then be up to temperature when cows come in and, with a warm digester and more slurry going through, there will be an increase in gas which can then be used to heat digester, with surplus gas for hot water and any other kinds of heating.

As a passionate and experienced advocate of renewable energy, Wyn Evans is happy to act as a practical consultant and has demonstrated the simplicity of the technology on a number of occasions, most recently demonstrating his mini-biogas stove which cooked sizzling Welsh cakes on top and baked potatoes in the oven.

10.5 Richard Tomlinson – Lodge Farm

Fast Facts - Lodge Farm Digester



Digester showing input tank (l), CHP enclosure (r) and mixing system (inset)

Digester Size: 1100m³

Digester Type: Mesophilic, gas mixed, insulated steel glass coated tank, fixed roof, internal heat exchangers with innovative de-gritting system.

Gas Use: 90kW CHP, FITs, heat used for main digester and small digester

Commissioned: Digester commissioned in July 2009, grid connected late 2010

Feedstock (T/yr): 30T/day of cattle slurry, from 650 cross-bred dairy cattle bedded on ash and wood chip; 3 T/day chicken muck
Supplementary organic substrates such as fodder beet fed in summer when cows are at grass

Farm Size: 405 ha; 80% grass, 20% arable whole crop (peas, barley triticale/barley, peas/vetch).

Capital Cost: £650,000 self funded, with £45,000 Smart Innovation Grant

Issues: Unreliability of CHP, grid connection problems

Barriers to AD:	Planning, waste legislation
Advantages:	Next step in responsible sustainable farming. Value of digestate. Diversification of agricultural business that is not under control of supermarkets

Richard Tomlinson is an innovative and successful organic dairy farmer. Lodge Farm has been organic for more than 10 years, selling milk to Calon Wen, the Welsh organic milk cooperative he was instrumental in setting up some 10 years ago. He developed a growing interest in AD and has been so impressed with the technology that he has set up his own company, Fre-Energy, along with some colleagues.

The Lodge Farm digester is unique in that, for more than twenty months, it has been successfully digesting a substrate that most digester manufacturers would shy away from, namely slurry where cows are bedded on ash. Ash has a tendency to fall out of suspension, even under strong mixing, and therefore tends to silt up a digester. Because this digester has a de-gritting system, mixing can be minimal, thus reducing the parasitic load and providing a certain degree of substrate stratification. Interestingly, this digester is being mixed far less than any other digester in this report, yet still produces good gas volumes and a well digested output.

There is also a 500l 'baby' digester on site which can be used for feedstock trials.

With FITs and a larger CHP, the operation is hoping to recover the capital cost in approximately 6 years. The digester cost £650,000 and was self-funded, apart from a £45,000 Smart Innovation Grant from the Welsh Assembly for the de-gritting technology.

Farm Type:

Lodge Farm is an organic dairy farm with 650 cross-bred dairy cows, set on 1000 acres of 80% grass and 20% whole crop. Cattle are kept in from November to the end of April and are buffer-fed in summer, that is, they are kept in the yard after milking and fed on cut grass.

As an organic farm, Richard aims for a 50:50 mix of clover and grasses/herbs (such as sheep's burnet, yarrow, chicory, ribgrass and others). Chicory is deep rooted and drought tolerant, and provides better drainage in wet times, breaking up clay pan. Minerals are contained in the herbs, so drastically reduce the bought-in mineral supply.

The farm's herd of cows are bedded on ash and woodchip.

Digester Description: There is no pre-processing of feedstocks; these can be processed within the digester. Seko mixer wagon loads chicken muck and mixes with slurry in QuickMix. Liquid slurry is fed directly into the digester from a holding tank. Richard feels that they definitely overspent on front end and, with hindsight, would have installed a mixing pit with chopper pumps and dump chicken muck straight in. This would reduce the £100K cost of feeder pumps down to about £10K.

The digester is heated to 40oC using internal heat exchangers and heat from the CHP. Slurry and chicken muck is pumped into digester, over 24 hours, little and often. Like a cow,

they don't want to be shock loading the system. As the digester is loaded, unloading occurs at same time, with digestate at about 5% DM being unloaded over an elevated belt press separator. Liquid goes into a lagoon and the solid fibre into a bunker. Retention time is 28 days.

The digester tank is a standard insulated steel glass coated circular Permastore tank 14.66m in diameter and 7m tall. The tank is mixed using a patented enhanced sequential unconfined 6 port rotary valve gas mixing system on a slowly rotating degritting arm. The system uses minimal gas agitation, just enough to stop any crust forming, since they are not agitating to keep grit in suspension. Gas is scrubbed by air injection into the top of the digester. The less agitation there is, the better the gas quality (~100-200ppm), because of the better surface scrubbing—you can see the sulphur eating bacteria white on the surface material of the digester.

About once a fortnight, grit at about 22% DM is removed for about 12 hours through the degritting system which can also deal with high levels of soil and stones without difficulty, e.g. from unwashed fodder beet. This removes about 8 inches grit from the bottom of the digester or about 14-15 tonnes. In volume terms, this is approximately equal to one digester volume every 7 months. Grit is put over the separator, as well.

Why does Richard prefer a digester with de-gritting? His cows are bedded on ash and woodchip. Ash has a very similar consistency to sand and will sink to bottom of digester. Richard notes that sand is the best bedding material by a margin: because it is inert, bacteria don't grow on it and it is a soft and comfortable bed, best for animal welfare. He believes that it is not in the best interests of good farming practice to have to change to a bedding system that is not as good for animal welfare in order to operate the AD system. This AD system is capable of dealing with both ash and sand and therefore complements the best animal welfare standards.

Gas is held in a 3.5m³ insulated bell over water gas holder and is used in an 88kW CHP. CHP heat is used to heat the main digester and the small digester. There is also an auxiliary gas boiler should the CHP not be available.

Parasitic load is about 1.5kW continuous for the mixing, de-gritting and water circulation. Liquid loading uses about .5kW and solids approximately 1kW.

Lodge Farm is also hoping to have a capped post-store.

There is also a 500l 'baby' digester, heated via the CHP, and used for testing other peoples' potential feedstocks such as meadow grass, apple pomace, chicken muck and so on. The advantage of this is that they can do live tests using the same bacterial loading as in the main digester; this provides accurate results on gas yields and the speed with which the gas is released. Richard has found that cattle slurry is a good main base load feedstock with good bacteria that enables you to co-digest other substrates.

Digestate Use: Digestate is separated, giving the farm the ability to target nutrient application more effectively. With more P and K in the fibre, it is put on arable land, with liquid going onto grassland. Currently, the digestate produced is needed on the farm. If he had a digester capable of processing more substrates than the farm is capable of using (such as food

waste), Richard would be happy to sell it to local farms, allowing them to offset their reliance on chemical fertilisers.

Lodge Farm has been organic for 11 years and Richard has not come across any soil deficiencies. He wouldn't analyse soil unless he had a field that he felt was not performing.

The farm is not in an NVZ, but there are similar restrictions for organic farms: 170 units N, which he believes is a sensible benchmark – any more and you are overloading.

The farm runs a paddock grazing system with a typical 21 day rotation around the paddocks, so timing is critical, typically having only a fortnight between digestate application and cow grazing. The use of digestate has much improved their flexibility in running this system because they are not concerned about rejection and their spreading window is greatly increased. With cow slurry, there is a risk of rejection on grazing land or contamination in the following crop.

Because the farm has some large watercourses running through it and is near the River Dee, they used to inject their slurry, but still worried about runoff when conditions were wet. However, now that BOD is reduced by 90% in the digestate, this is much less of a worry. Digestate is applied using a spike aerator with a driller bar behind it because they didn't feel that the injector was getting in deep enough, only about 2"-2.5", compared with 5-6", which provides better aeration of the soil.

Trials have been carried out by the University of Glamorgan who asked AD plants to send in digestate, although they have been given no feedback as yet. Currently, growing trials are being monitored by Bangor University, with initial results being very promising, indicating a much improved uptake of Nitrogen compared with normal slurry. This year, they are hoping to do fields size trials with digestate vs slurry. Southampton University is carrying out a study on the effects of digestate on worm mortality, with formal results to be released soon.

Gas Use: Gas is used in a Beaver Power/Perkins Quantum 88kW CHP. The digester produces approximately 50m³ biogas per hour and is scrubbed mainly by air injection, maintaining an H₂S level of between 100-200 ppm. There is an auxiliary gas boiler to allow excess gas to be burned and to provide heat for the digester when the CHP is down for maintenance.

FITs are claimed.

Issues with the Installation: Richard opines that by far the biggest problem with the AD installation is the CHP and their system is no exception. His advice to farmers is to buy a good CHP and regards keeping it going as a 'black art'. He believes that all farmers have the basic knowledge to feed a digester: they understand cow nutrition and digester nutrition, but not all have the specialised engineering skills to keep a CHP running. He says that CHPs typically cost ¼ of the price of the whole plant and would recommend that a CHP is bought with a maintenance contract attached.

Legislation, Licensing and Regulation: Grid connection has been an absolute nightmare, extremely expensive and very, very slow getting the connection put in. He feels they were bounced around too many departments and there is clearly not a will for the power to hook up to a renewable energy source. They chose FITs, as there was uncertainty around double

ROCs both in terms of eligibility for a grant aided digester and because banks want long term assurances and not fluctuating income streams.

He adds, “Most of the problems were with other bodies, planning and licensing. Building the digester was the easiest. Planning was a nightmare and we had to educate planners. You would expect them to go away and do research, but they don’t and anything they don’t understand they say no. The local community were involved from the beginning and were very supportive, over 90%. So planners used highways to justify the ‘no’. If the non-feed grade material was being dumped to land, there would be no problem, but their planning restriction does not allow them to put it into the digester first, as planners said that they would then become a ‘waste treatment facility’. They failed to appreciate that the size of the digester and the land base precluded this. There would be, at most, 15T spare capacity in the digester and the highway movements involved with this would still be half of those if I operated my farm with high inputs. We could easily bring substrates on farm if they were fed to the cattle, but not if they were being fed to the digester.”

In order to improve cash flow, FITS could be paid monthly instead of quarterly.

Recordkeeping: Richard says that “The most important thing to know is what is going in and what is coming out of the digester, which gives a figure on how efficiently you are feeding it. Temperature must be monitored, since they don’t want it too cold, as they won’t get the best utilisation of feedstock. We have viewing ports to see how much agitation is needed. We need to know the quantity and quality of the gas we are producing for the CHP.” He also believes that there should be monitoring to evaluate how efficiently these digesters are working and believes PAS 110 should be implemented, but at an affordable level, where testing is done on digestate the same way it is done on his milk.

Training has been experiential.

Advantages of the Digester. Richard believes that one of the greatest advantages is the major improvement in utilisation of cattle slurries and production of a soil friendly fertiliser. Another advantage is being able to use renewable energy back on the farm rather than importing energy that is produced from coal.

He would heartily recommend AD, as he sees it as the next step in sustainable farming. Richard says, “I particularly like the fact that it gives you a second income stream which is non-food based, out of control of supermarkets and is an income stream which is clearly only going to improve. Any other agricultural activity is largely controlled by supermarkets and the price of production bears no resemblance to the purchase price. By getting into renewable energy, there is a growing market and increasing demand. Lodge Farm has done 3 business plans between project inception and completion and each time, the business plan improves.”

“I particularly like the fact that it gives you a second income stream which is non-food based, out of control of supermarkets and is an income stream which is clearly only going to improve”

Barriers to on-farm AD – Richard believes that the biggest barrier to on-farm AD is “red tape, planners, EA, people who don’t understand and don’t read government guidance notes. Government has clearly stated they want to support AD, but civil servants further down the food chain are not informed. The easy answer is always no and that appears to be their philosophy. Finance is another huge barrier and we have had chats with bank managers who say that they won’t fund the plant without equity and are asking for the farming business to cover the whole costs, assuming the digester doesn’t produce any income at all. There are not many farming businesses who can service large loans at 6%. Banks are looking for 100% security. Unachievable for about 99% of farmers.”

The farm twice tried to attract part of £10M WRAP funding for AD in Wales, but were unsuccessful on the grounds that expert opinion felt the system wouldn’t work. Of the ones who were successfully grant aided, none have yet been built. The only digester which has been built was Lodge Farm’s and they did not get the grant.

10.6 Colin Risbridger – Tuquoy Farm

Fast Facts - Tuquoy Farm	
	
<i>Digester 2 on left; digester 1 under slats in shed on right.</i>	
Digester Size:	Digester 1 – Under slatted cow shed – 75m ³ Digester 2 – FGB Style – 175m ³ Digester 3 – 2m ³ portable digestion plant
Digester Type:	Digester 1 – Insulated underground concrete digester, gas mixed, mesophilic, fixed insulated GRP roof, internal heat exchangers Digester 2 – Insulated underground GRP digester, gas mixed, mesophilic, internal heat exchangers Digester 3 – Steel tank, jacketed with 50mm PS and GRP
Gas Use:	Two 9kW CHP and gas boiler
Commissioned:	Digester 1 – 2006 Digester 2 – 2008 Digester 3 – 2009
Feedstock:	Slurry from 144 LSU housed indoors on slats 8 months of the year ~ approx 6T/day, 2,190 T/yr Additional 200T/yr grass silage when affordable
Farm Size:	Beef, cattle and sheep, 440 LSU housed on slatted courts.
Capital Cost:	Digester 1 - £80,000, grant assistance from Orkney Enterprise and Orkney Islands Council Digester 2 - £220,000, helped with £98,000 from Scottish Biomass Scheme and £24K Leader assistance Digester 3 - £10K with funding assistance from Seafish.

Issues:	Grid connections of the engines. Scrapers in shed under slats occasionally stick. Income levels too low to repay capital investment currently.
Barriers to AD:	FIT rates too low; RHI should include heat used by the digester; should be a de minimus rule to include small quantities of other wastes (<1-2 tonne/week or 2.5-5% of feedstock); partial refusal of Quality Meat Scotland to accept digestate with non-farm wastes.
Advantages:	It solves a number of problems at once, not least of which is nutrient recycling, production of energy, reduction of odours, reduction in weed seeds and pathogens in slurries, makes N more readily available for plant growth, provides increased confidence in the future of farming and much more.

Colin Risbridger has had a long-standing interest in developing renewable energy projects, with particular interests in tidal and wave power, wind power and anaerobic digestion. In 2004/5, he began working with the Westray Development Trust who planned to build a community digester and community wind turbine. Vicky Heslop was employed as a consultant to advise on feedstocks and sizes. However, it quickly became clear that there was an issue regarding the co-digestion of slurries from various farms and potentially other wastes from the local community because of the issues raised with the farm quality assurance scheme. It became obvious that a quality standard was required for the digestate to be returned to the farms in order to not affect the quality assurance. Colin Risbridger secured funding from Highlands & Islands Enterprise and Scottish Enterprise to create a Scottish Digestate Standard and this scheme led on to further work to create a UK standard and the project was funded by SEPA and WRAP/REA. The initial work inspired by Colin's project was carried out by Vicky Heslop, Reading University and David Collins at the REA, but as the perceived importance of this grew, it was taken over by WRAP and DEFRA and has now resulted in the PAS110 digestate standard and protocol in which all parties are credited.

Due to the time taken to develop the digestate standard and the lack of clarity of the legislation regarding such a scheme at the time, the WDT renewable community scheme, which had a site, planning permission, funding and widespread community support for a 600 cubic metre digester, was largely abandoned, except for the 900kW wind turbine which has been built and was commissioned on the 3rd October, 2009.

As a renewable energy engineer, the failure of the AD side of the WDT project did not stop Colin, but led him to develop his own smaller scheme in partnership with local engineer Sam Marcus and the family farm which is described here and he continues to work on a large number of renewable energy schemes in the Orkneys and beyond. He has formed the not for profit group Energy Action Westray to reduce the island's emissions by 80% by 2050 (www.care4energy.co.uk), is constructing his own wind project with 2 x 900kW turbines in 2011, sits on the Community Energy Scotland board and provides energy advice services for the Energy Saving Trust advice centre and support to Scottish Power on the Marwick Head 50MW wave energy project.

It should be noted that SEPA has issued a regulatory statement which deems PAS110 acceptable in Scotland provided that certain additional criteria are met; however, Quality Meat Scotland continue to partially refuse to accept digestate with non-farm wastes. After years of campaigning, QMS have recently allowed its use on combinable and oil seed crops, but not on grassland or other crops where cattle and sheep have contact with the soil.

The projection was to be able to grid connect up to 50kW electrical output with two 25kW single phase connections and the intention was to use grass silage bought as an energy crop. The FiT rates (and before them, the ROCs) are not enough to merit purchasing the energy crops and they are used instead for cattle feed and the economics therefore have been very poor with no additional income for capital repayment.

Farm Type: Tuquoy Farm is a mixed farm located on the Scottish island of Westray. Beef cattle and sheep are raised as store animals on the farm, with animals being housed on slats for approximately 8 months of the year. Of the farm's 440 beef livestock units (LSUs), slurry from one byre (which houses 144 LSUs) is used in the digester. The farm owns 500 acres and rents a further 500 acres and is self sustaining in cattle feed with Barley and Grass silage used for feed.

Digester Description: The first digester was installed under the cattle shed to look at the viability of integrating it with the existing slatted tank system without the need to build a separate digestate store.

Digester 1 utilises the existing rectangular 75m³ concrete tank, with new partitions insulated down the two long walls with 50mm PS, with an insulated GRP roof and internal heat exchangers. It is gas mixed with a 36 port rotary valve and heated to mesophilic temperatures.

Digester 2 is a low-energy shaped 175m³ 50mm PU insulated GRP digester, set onto a concrete base insulated with 50mm PS. It is an FGB style digester; that is, it is a Farmgas type 'B' unit, heated by internal heat exchangers to mesophilic temperature and mixed using a 36 port rotary valve.

When the second digester was built, it was designed to work with Digester 1 as a multi-tank process. Under the slats, scrapers push slurry into flow channels, continuously feeding Digester 2. The feed system into Digester 2 also includes a feed well and auger to help add solids such as grass silage.

There is a separator in place, but it has not been used.

Digester 3 is a 2m³ portable steel jacketed tank, coated with 50mm PS and GRP, mixed via PTO driven Landia chopper pump. This digester is only used for batch processing trial feedstocks.

The digesters were self-built, with mixing valves and some engineering consultancy supplied by James Murcott, gas pumps supplied by Utile, boiler by Hamworthy and Lister Petter engines.

"We could install a 6kW turbine for £30k and get 23.7p/kWh FiT ...compared to the digester which cost in the region of £250k and we would only 11p/kWh FiT, much uncertainty whether we would get RHI on the heat we use,.. It is easy to see why no-one is investing in small scale AD at the moment."

Digestate Use: Approximately 2200 tonnes of digestate are produced annually. Digestate is not separated, as there is no market for solids, so it is used on-farm. Digestate is spread mainly on grass silage and a limited barley crop, with chemical fertiliser supplementation.

Crab shell waste was trialled in the small batch plant, in conjunction with Seafish and the results disseminated. Additionally, crop trials on the digestate were carried out as part of an MSc project.

Gas Use: Two CHP units, each 9kW. Currently, only one is used and is connected via a 6kW inverter.

Issues with the Installation: The biggest ongoing problem was in trying to connect the 9.8kVA Lister Petter propane engines to the grid, since they were not stable enough to synchronise (frequency problems). Colin recently bought a 6kW inverter to separate the engine frequency from the grid frequency and they have now managed a stable connection producing a steady 2.5kW continuously.

There has also been a problem with the scrapers periodically sticking. Additionally, there was a problem with the sealing of one of the 36 port rotary valves to the digester.

Legislation, Licensing and Regulation: Colin has explored a number of avenues in trying to make AD work on this project and others, but boils his issues down to the fact that regulation has been “an absolute nightmare which prevents us using any other feedstock. The main problem is Quality Meat Scotland and their refusal to accept digestate with non-farm wastes and their lack of co-operation in researching the perceived risks to reduce uncertainty.” They have recently partially relented on this point, and now allow the use of this digestate on land used for growing combinable and oil seed crops.

Record Keeping: None

Training: Experiential or, as Colin puts it, “Learn the hard way.”

Advantages of the Digester: It solves several problems all at once and unfortunately this is why government cannot incentivise it correctly.

Barriers to on-farm AD: With his experience in a wide variety of renewables, Colin makes some valid points: “The FiT rates are far too low and the proposal not to include the heat used by the digester in the RHI is just plain stupid. Also, there should be a de minimus rule to include small quantities of other wastes (eg up to 5%) without regulation.”

He adds “We could install a 6kW turbine for £30k and get 23.7p/kWh FiT with production 40% of the time compared to the digester which has cost in the region of £250k and we would only get 11p/kWh FiT, much uncertainty whether we would get RHI on the heat we use, even though we operate 95% of the time. It is easy to see why no-one is investing in small scale AD at the moment. There is talk of linking renewable to the single farm payment which would be great and create another incentive but we need to be sure that this will also allow farmers to contract with community groups to handle the material.”

10.7 Worcestershire Digester

Fast Facts - Worcestershire Digester



Photograph of digester under construction in 1992

Digester Size: 220m³

Digester Type: WRI steel tank with insulated glass fibre roof, 36 port gas mixing and internal heat exchangers.

Gas Use: Heating the digester; local use.

Commissioned: 1992

Feedstock (T/yr): Currently, around 120 dairy cows, although originally about 200 cows.

Farm Size: 250 acres (101 ha)

Capital Cost: 50% Grant.

Issues: Flooding during construction.

Barriers to AD: Excessive cost and complexity of small scale CHP. Level of FITs. Historically, the adverse stance of advisors, e.g. ADAS

Advantages: Improved slurry management and improved nutrient recycling. Simplicity of the system.

This small AD system is included as an example of small scale simplicity where the farmer does not handle his slurry at all from when it leaves the cow to when it arrives on the field.

The digester was originally built when the farm had 200 cows. The farmer needed a new lagoon, so the old lagoon was pumped out and cleaned and the digester was installed in the bank of the old lagoon so that slurry could flow directly out from the cows into the digester without intervention. A new lagoon was dug nearby so that the liquid fraction could be easily pumped to the fields.

Recently, in order to introduce two robotic milking parlours, cow numbers reduced to around 60 cows and have now levelled off to around 120 cows, with the digester coping admirably with these fluctuating numbers.

Farm Type:

Dairy farm with cows housed in cubicles all year round. Cows are bedded on mats dusted with sawdust or commercial disinfection/drying powder.

Land is used for grass cutting on a zero grazing system and for grass silage. Typically 50 acres of wheat/beans, 30 acres of maize, 30 of grass and 140 acres of grass silage are grown.

Digester Description:

Slurry is scraped out of the shed by automatic scrapers four times a day into a flow channel flowing directly into the digester which is situated no more than 10 metres away from the shed. Slurry flows directly into the digester without the aid of pumps or other handling equipment and, due to volume of flow channel, enters the digester fresh and undiluted within a day.

“We are hoping to install a 27kW single phase generator (the farm is only on single phase). However, we are hoping that FITs for small-scale AD can be revisited by then so that they are more in line with other renewable technologies.”

The digester is an epoxy coated steel tank, with internal GRP coated insulation panels and an insulated GRP roof. Mixed with a standard WRI 36 port rotary valve gas mixing system and heated by 1 circular heat exchanger. The digester is heated by a cast iron biogas boiler with fully automatic controls.

Gas holder is 1.5m³ insulated GRP bell over water gas holder.

Outlet is 150mm diameter pipe with automatic variable speed auger feeding onto a belt press separator, with fibre bunker underneath. As the digester is emptied, a similar volume flows in. Liquor is pumped away to the lagoon approx 100 m away using a submersible transfer pump.

Yearly running costs are about £1800 per year. This roughly breaks down as follows:

- Mixing pump 2.2 kW, running 33% of time costs about £45/month
- Separator 3 * 0.37 kW, running 66% of time costs £45/month

- Liquid transfer pump 2kW, running approximately 1 hour/day costs £5.50/month
- Separator belts 3 or 4 per year, plus sundry items £600/year.

Digestate Use: Liquid digestate is pumped through an irrigation main which is laid around the farm with attachment points for a Briggs Roto-rainer travelling irrigator with trailing lay flat hose. The farm operates a zero-grazing system, so grass is cut on a daily basis to feed to the cows and the Roto-rainer is set up to follow on behind the grass cutting forage harvester. This quick and efficient operation usually involves the use of a quad bike which is used to unreel the winch cable which is pegged into the ground at the far end of the field and then, on returning to the farm, the pump is switched on. The system then automatically irrigates the field and, when finished, turns itself off.

Gas Use: Gas is used to heat the digester, as well as elsewhere. The farmer notes “When cattle numbers are back up to full herd size, we are hoping to install a 27kW single phase generator (the farm is only on single phase). However, we are hoping that FITs for small-scale AD can be re-visited by then so that they are more in line with other renewable technologies. For small-scale installations such as mine, the cost per kW of these small sub-50 kW CHPs is considerably higher than larger CHPs.”

Issues with the Installation: During construction, a flash flood occurred where water poured into the empty lagoon, completely filling it and causing the newly-built digester tank to float away. The tank remained absolutely watertight, so was towed back into place and secured, whilst the lagoon was pumped out. The digester settled down within 1 inch of level and there it has remained, with no floods occurring since. Otherwise, no issues.

Legislation, Licensing and Regulation: No problem with installing digester in 1990.

Record Keeping: Not necessary. Farmer checks: is digester up to temperature, is it mixing and is the separator running when it should be. Slurry flowing out allows slurry to flow in automatically by displacement. Occasionally looks at temperature gauge on control panel.

Training: The digester came with a fully automatic control system, is very simple and basically runs itself, so little training was needed.

Advantages of the Digester: The digester has proved itself to be totally worthwhile purely on the basis of slurry management. The system is so simple and it just works. “I used to think I was making good use of my slurry, but since having the digester, I now realise that I wasn’t”.

Barriers to on-farm AD: Increasing complexity and lack of clarity on legislation, especially with regards to ‘wastes’. Historically, the adverse stance to AD of advisors such as ADAS also limited the uptake of the technology.

10.8 Shropshire Digester

Fast Facts - Shropshire Digester



Digester showing boiler/control/separator kiosk on left and digester tank on right.

Digester Size:	300m ³
Digester Type:	Epoxy coated and galvanised coated steel tank with insulated fibreglass roof, internal heat exchangers and 36 port rotary valve gas mixing
Gas Use:	Heating the digester and a large manor style house
Commissioned:	1991
Feedstock (T/yr):	Slurry from 300 Jersey cows housed from Oct - Apr
Farm Size:	1000 acres arable
Capital Cost:	£45,000 with a 30% grant
Issues:	Long straw
Barriers to AD:	None
Advantages:	Primary advantage is that there is no slurry problem. Ease of spreading

This Shropshire digester is included in the case studies, because of its longevity and simplicity of operation. It was built in 1991 by WRI and is unique amongst these studies, as the owner is not personally involved in the day-to-day running of the digester. Additionally,

digestate spreading is carried out by a third party, as is digester maintenance. However, the farmer still retains his digester primarily for the ease of slurry handling and smell reduction – quite an amazing thought when you consider that he has saved tens of thousands of pounds in heating a large manor house, but actually considers this to be secondary over the benefits of the improved slurry handling and use of digestate.

Farm Type: This Shropshire farm is a large farm with approximately 300 cattle plus followers and 1000 acres of arable land. Cattle are kept indoors for 6-7 months of the year.

Digester Description: Twice daily slurry is scraped directly out of the sheds into a pit where it is augered into the digester. The farm hand sets the outlet auger running and digestate is separated over a belt press separator, with fibre falling into a collection area beneath the separator and liquid being pumped to a nearby lagoon. The amount augered out of the digester controls the amount augered in.

The digester tank itself is about 10m in diameter and 4m deep and is largely buried into sloping ground, level with the end of the shed. The tank was originally insulated with sprayed PU foam on the inside which appears to have deteriorated, causing higher heat loss than when originally installed. The tank is covered with an insulated fibreglass roof. A control kiosk houses the biogas boiler used for digester heating, a control panel and a belt press separator. Heating is done by internal heat exchangers.

“...you get rid of the slurry problem...”

Gas is held in a 1.5m³ insulated GRP bell over water gas holder.

The digester remains at ambient or near-ambient when the cows are out. Then, in September, a service engineer comes in, does any necessary maintenance and brings the temperature back up in preparation for the cows coming in. Bills for this maintenance have risen from £1300 in 2007 to about £1900 in 2009 and comprise the bulk of the running cost, outside electricity for the gas compressor pump, augers and separator, which is not monitored, but not regarded by the owner as significant.

Digestate Use: The liquid fraction is injected into arable fields, whilst the solid fraction is used as necessary, mainly on grassland.

Regular soil sampling is carried out and the farmer still adds some bought-in Nitrogen.

For a number of years, the digestate was blended and sold as award-winning⁴⁴ Heritage Compost, again by a third party, but this did not prove economic, especially when compared with cheaper Local Authority compost. He would not now consider doing this, although has over the years made digested fibre available to eager gardeners.

Gas Use: Gas is used to heat the digester and to heat a continuously running 30kW boiler for house heating. This would be roughly equivalent to 90l of oil per day. With current prices of oil running at 70p/litre, this would be in excess of £63/day.

⁴⁴ Better Environment Award 1992

Issues with the Installation: Cows were originally bedded on long straw and this did cause some problems and did not digest well. In addition, the rising price of straw meant that the farmer changed to chopped straw and the digester has run well since.

Legislation, Licensing and Regulation: None encountered when digester was built.

Record Keeping: Cost of yearly maintenance.

Training: None really necessary—farm hands were shown button to start outlet auger (which they prefer to run manually). They can see the separator operating, the gas holder and the mixing working from anywhere in the yard. In the event of any problems, the maintenance engineer is called out.

Advantages of the Digester: Primary advantage is that you get rid of the slurry problem. Also, ease of spreading.

Barriers to on-farm AD: Possibly cost, as farmer received grant aid of 30% to defray the cost and these grants are no longer available.

10.9 Clive Pugh – Bank Farm

Fast Facts - Bank Farm



Clockwise from top left: proposed digester 1 site; new digester; substrate on grass trials and covered digester post-store.

Digester Size: Digester 1: 265m³
Digester 2: 3 x 175m³

Digester Type: Digester 1: WRI mesophilic gas mixed, insulated steel tank with an insulated GRP roof and internal heat exchangers
Digester 2: Three stage concrete digester tanks, mesophilic, gas mixed, with insulated GRP roof and pasteuriser

Gas Use: 124kW CHP, plus house/hot water heating for 2 houses using Rayburns running on biogas. Hoping to do all with CHP recovered heat, 80kWth goes into digester, 100kWth will be used to heat dairy washings and 2 houses, still keeping Rayburns.

Commissioned: Digester 1: 1990
Digester 2: 2002

Feedstock (T/yr):	Feedstock is currently slurry from 130 dairy and 150 beef cattle housed half the year (approx. 2500T/yr) Chicken muck: approx. 150 tonnes Waste silage: approx. 30 tonnes Bought in waste: e.g. bread waste Used animal bedding, mostly in summer Crops: sugar beet, potatoes and grass grown on farm
Farm Size:	131ha, with an additional 35 ha of rented land. Approximately 280 head of cattle, 350 ewes and some poultry.
Capital Cost:	Digester 1: WRI approx £75,000 with 50% MAFF grant £37-£38,000 (digester and post-store) Digester 2: approx. £105,000 with grant aid from £50,000 Montgomeryshire Rural Enterprise. Cover for post store: Helped with £22,000 grant aid from Glasu CHP: £103,000 plus commissioning Clive estimates a total cost of £500,000 (with modifications and experimentation) of which £50,000 was grid connection costs.
Issues:	Grid connection and ongoing issue of load balancing. New mixing installed in digester 2.
Barriers to AD:	Cost of grid connections. Difficulty in getting local high strength wastes onto the farm in order to improve the economics.
Advantages:	Numerous personal and environmental gains, including spending less money on fertilisers, electricity and heating, as well as reducing pollution from slurry off-gases and run-off

In the late 80's, Clive Pugh became interested in anaerobic digestion because he needed a new slurry store and, with local companies like Farmgas and Waste Refineries International, they had been aware of the technology for a number of years. The first digester was 50% grant aided from MAFF to replace a 'hole in the ground' slurry store and the digester provided the answer to the safe treatment and use of the slurry.

After 10 years of successfully running the digester on farm residues, Clive, in his visionary aim to become energy and fertiliser self-sufficient, as well as to export electricity, took the bold step of building a second digester which could take in outside substrates. In order to successfully achieve this, Clive approached his long-standing friend James Murcott who designed a three stage state-of-the-art digester and pasteuriser, with the only covered digestate post-store in the country. Construction was undertaken as a self-build by Clive, with GRP and other key components supplied by James at Methanogen.

Clive's carbon neutral vision was way ahead of its time and he is no stranger to bureaucracy, having encountered it whilst trying to use various outside substrates on his farm, as well as

being one of the pioneers in attempting to use CHP on-farm at this scale. He successfully digested green waste from the local council, but much of this subsequently was taken to the digester at Ludlow and then elsewhere. He now buys in substrates, costing about £20,000 per year. At one stage, bio-diesel plant Sundance, 65 miles away near Ammanford, considered a number of uses for their glycerol, including sending it to local AD plants, such as Pugh's, in order to save on costs of transporting to Holsworthy (approx 225 miles away), but this was never effected.⁴⁵ Clive does not use glycerol in the digester because when he approached Ofgem, they told him that they would not pay ROCs on it, although he has had difficulties in clarifying this issue. He feels it is a pity, because it makes good gas and might otherwise be going to waste.

The digesters have been serviced for many years by Jimmy Ellis, whose experience in this field from Farmgas, through to Waste Refineries, Digester Spares & Maintenance, Greenfinch and, finally, Marches Biogas has proved invaluable.

Farm Type: Bank Farm is a mixed farm on 131 ha with 130 dairy, 150 beef cattle, 350 ewes and some poultry. 35 ha are also rented. Sugar beet, grass, potatoes and other crops are grown on the farm.

Digester Description: Slurry is scraped directly into an input pit for Digester 1 and augered into the digester using a 17" auger. The digester is gas mixed using a 36 port rotary valve and there are two internal heat exchangers. This digester has been emptied once during its twenty year operation, a process which took about 4 days. Output is augered out with a 5" auger straight over a Farmgas belt press separator. Gas is held in a standard bell over water gas holder.

Digester 2 is a more unusual configuration and consists of a large oblong 3 stage tank. Each tank holds 175m³ and measures 3.5m x 10m x 5.3m deep. They are mixed using ten six port rotary valves. Heat is provided by 3 internal heat exchangers, one are hung from each of the 3 insulated fibreglass roofs. Each roof section also has an integrated bell over water gas holder. The digester includes a 2 tonne batch pasteuriser unit which reaches 72 degrees, but this has never been used, although it could be. The digester is capable of coping with 24 tonnes per day. Clive notes that he gets a lot better digestion with this 3 stage tank.

The feed in system for the digesters is flexible enough that Clive can use a wide variety of feedstocks into the digesters, including poultry manure, farm yard manure, silage effluent, waste silage, discarded milk, green waste, potatoes, sugar beets or any other organic substrates available. The feed system consists of a big hopper with an auger chopper which can mix 20-30 tonnes at a time, chopped up by an 18kW Landia chopper pump running off the tractor. This thick soup is then automatically fed overnight every hour into the digester running on a timer.

The digesters are heated to between 38°C and 42°C.

Separated liquor goes into a covered post-store, where gas is scrubbed using air injection and any off-gases are captured. The post-store is covered by a large insulated GRP roof.

⁴⁵ <http://www.ecodyfi.org.uk/pdf/biodiesel.pdf>

In addition to the ~£20K cost of buying in feedstocks, the annual running costs for the digesters are about £3000 per year for CHP maintenance, including filters, oil, spark plugs and so on, with oil being quite expensive.

Because the gas scrubbed in the post-store is of such good quality, Clive has been able to reduce costs associated with the CHP, for example, it was recommended that spark plugs be changed every 2000 hrs, but one set lasted 6000 hrs before they needed changing.

It takes Clive about one hour a day to check that everything on the plant is working well.

Digestate Use: Approximately 3000 tonnes/yr of digestate is produced by both digesters, consisting of about 20% fibre, 75% liquid and 5% gas. All the digestate is separated into both liquid and fibre. As Clive points out “This makes better use of the product because spreading onto the land is more accurate: liquid is spread using a slurry tanker and the fibre is spread with a muck spreader. The solid digestate or fibres are good for clay and sandy soil because it increases the humus. The amount of digestate we produce is always used solely on our farm. We do not use unseparated digestate because of its inaccuracy when spreading. Separation is a simple process done by a belt press.”

He is very aware of the value of the digestate on his land, adding, “In fertiliser terms, 1000 gallons of separated liquid will provide around 30 units of nitrogen, 40 units of potash and 12 units of phosphate, depending upon the feedstock. The quality of our grass is certainly most noticeable, and our need for phosphate and potash is now nil. We only need to top up nitrogen depending upon the type of crops being grown.”

As with other correspondents, Clive points out how his spreading window has increased because the digestate does not contaminate silage or grazing grass, noting the willingness of cows to graze more quickly after spreading. Although the AD process reduces pathogens and kills weed seeds, he could achieve a total pathogen kill if he used the pasteuriser on his second digester.

Gas Use: Gas is used for house and hot water heating in two houses and in a IET 124kW CHP. Currently, 80kWth recovered from the CHP heats the two digesters. They plan to use the other 100kWth to heat the two houses, plus dairy washings (over 150gal/day) and are considering other farm uses such as grain drying. The Rayburns will continue to run on biogas. Clive currently receives ROCs (as he was unable to access FiTs), but is hoping to also be able to take advantage of the RHI.

The CHP produces about 70MW in a month, approximately 2500kW/day or 90-100Kwh.

Issues with the Installation: Installation of both plants went relatively smoothly, with a few teething problems which were solved. Clive felt that improvements could be made to the mixing on Digester 2 and commissioned a new mixing system.

The digesters need de-gritting every 5-10 years.

Clive would confidently recommend his particular CHP, which he feels is excellent; however, a problem with a switch just before the Christmas shutdown meant they lost some electricity production for about a third of December.

Legislation, Licensing and Regulation: Because Clive has been years ahead of his time in wanting to recycle nutrients on-farm from the widest variety of local sources of organic feedstocks, he has run into a great deal of bureaucratic vacillation. In general terms, if there is no guidance or the guidance has been unclear, the answer has been 'no'.

A particular nightmare has been with the grid connection and associated incentives. Clive installed his CHP long before FITs had been envisaged and he has not been able to access the FiT tariff, which means he is losing around £100 per day. It took the farm around 4 years to obtain the grid connection, with Clive wryly noting that his son has around 16 contact numbers, and would just about establish a relationship with a contact, only to subsequently find that they had moved, been promoted or couldn't help! Clive felt that the cost of the grid connection was excessive, as well.

Finally, there have been ongoing problems in trying to balance the load on the CHP, meaning that it could not run at its optimum output. Clive feels that this has largely been sorted out now, although points out that the DNO is planning on charging future customers for rectifying load balancing problems—something which he finds rather ironic, as a recent renewables expert pointed out that producers like him at the end of the line help mitigate the central distribution losses of pushing electricity down to these furthest reaches. He feels that it is the mindset of these companies who, although they have to connect you by law, don't really want to.

Record Keeping: Although Bank Farm carries out regular soil analysis as part of its arable operations, no other records on the digester are kept. They do keep careful records of electricity production figures from the CHP.

Training: Basic training was given by WRI, but the bulk of knowledge and training has been experiential.

Advantages of the Digester: Clive lists the following personal and environmental gains from using the digester:

Personal Gains:

1. We spend less money on artificially produced fertiliser and hopefully, in the future, none.
2. We have reduced heating bills in the home and on the farm. The farmhouse is constantly warm.
3. We feel content that we are safer from causing pollution from escaped slurry and silage effluent.
4. At one time, we were paid for taking green waste by local councils. We now take other substrates as allowed.
5. We use farm manure more efficiently.

Environmental Gains:

1. We are recycling the methane gas in waste and putting it to good use, thereby helping to prevent global warming.
2. By not using artificially produced nitrogen, we are not only saving transportation, but also the process of production of nitrogen which takes huge amounts of fossil fuel.
3. Saving fossil fuel use in many ways.
4. Avoiding uncontrolled composting which produces large amounts of off-gases.

“Digesters have got to come and they want driving, whether there are barriers or not”

He adds, “We find the digester way of farming useful, interesting and rewarding. We would be glad to encourage others to go down the same route.”

Barriers to on-farm AD: “We have been disappointed that the National Government has shown such little positive interest in this form of treatment of organic substrates and Green Fuel production. Germany, Denmark and Austria are way ahead of us and receive help and interest from their governments. As long ago as 2004, Austria produced more than 70% of its electricity using non-fossil energy and the UK is far behind because of lack of proper incentives and joined up thinking which allows farmers to easily take local organic substrates in order to supplement their incomes and improve the economics of reducing their carbon footprint.”

He feels that grid connections are a barrier, as they could be more streamlined and less expensive, and he has lost countless man-hours of his time in trying to organise the connection, taking away from his main job which is actually running the farm.

Clive is in touch with other farmers who are interested in the technology and points to a case where planners are creating problems for a digester installation with an environmentally sensitive species on the farm, saying that the bureaucrats just don't realise that the alternative of using a digester and its digestate is so much better for the environment than the muck piled in a heap in the farmyard, with its potential for leaching and emissions.

When asked what he feels barriers to AD are, Clive makes a very interesting point “Digesters have got to come and they want driving, whether there are barriers or not. There will be some people that will run them very well and some that will struggle, but it needs to be on the farm. These organic wastes need to go back to fertilise the land with the energy taken out of them and used for heating and electricity. There is a cost of setting it up and learning how to run it, so it is going to be a learning curve for farmers. And, unfortunately, there is a fair bit of bureaucracy, as well as planning issues.”

Having been in both situations, Clive feels that there is room for people who want to build digesters and use the gas on farm, as well as those who have access to extra feedstocks and want to generate electricity. However, if just using gas on the farm, he would advise people to try to keep them going all summer, as it requires very little extra to do so, especially since the manure doesn't take much heating.

SEC Funded Digesters in Scotland

The 7 Scottish digesters in Ayrshire and Dumfries were funded by the Scottish Executive as part of a number of measures to improve the bathing water quality in local seaside beaches. It was hoped that the digestion process would destroy harmful organisms in the slurry, so that when the digestate was spread on the land, there was less chance of harmful organisms entering the local watercourses and, ultimately, the beach.

Part of the initiative involved Greenfinch (subsequently Biogen Greenfinch) maintaining the digesters for the first five years before handing them over to the farmers. Because of this arrangement, capital costs have been estimated by the farmers and annual maintenance costs (outside the electricity cost for the plant) are estimated or unavailable.

Whilst only 4 of the 7 were interviewed, these digesters make very interesting case studies for a number of reasons:

- the digesters were funded by the Scottish Executive, so the normal dynamics associated with 'return on investment' were not a factor, and varying levels of engagement with the system could be observed;
- farmer time and effort, as well as monetary costs associated with planning, regulatory acceptance and licensing were non-existent due to the drivers and scale of the projects;
- whilst digester size varied, the technology in terms of feeding, pumping, control, mixing and storage was largely the same. However, the farm slurry management regime varied between farms;
- other than electricity bills for the plant, which were not generally considered to be excessive, the maintenance and parts for the first 5 years were covered, so the farmers could almost regard AD solely in terms of the benefits of the process itself and the time/effort it took to run the plant.

10.10 SEC: Wesley Millar – Ryes Farm

Fast Facts - Wesley Millar	
	
Digester Size:	250m ³
Digester Type:	Mesophilic, gas mixed, round insulated steel glass coated tank, fixed glass coated steel insulated roof, covered in fibreglass, external heat exchanger.
Gas Use:	Small Rayburn cooker, digester heating
Commissioned:	2004
Feedstock (T/yr):	Slurry from 100 head dairy cows plus 250 young stock.
Farm Size:	110 ha, 5-10 ha planted with spring barley; the rest split equally between grass silage and grazing.
Capital Cost:	N/A, estimated by farmer to be between £200K & £250K
Issues:	No significant operational issues, other than reception tank gritting up, however, insufficient gas was available to heat the house as hoped.
Barriers to AD:	Capital cost of the unit.
Advantages:	Digestate much better product than raw slurry

Farm Type: Ryes Farm is a 110 ha dairy farm based in Dumfries which has 100 cows plus around 250 young stock, with calving all year round. Cows are generally housed about 7 months of the year, coming indoors in September-October and going outdoors around May. The cows are on slats and are bedded on sawdust or, currently, recycled paper.

Five to 10 ha are planted with spring barley and the rest is split between silage and grazing. Feed has to be bought in for winter. As with many dairy farmers, Wesley Millar tries to keep his inputs as low as possible and, with rising feed prices, is considering switching to a New Zealand system. The farm is not in an NVZ.

Digester Description: Slurry flows into tanks underneath the slats. Slurry from the four holding tanks in the two open sheds is then pumped about once a week into the reception tank. The tank in the older shed is pumped down a bit every week, as the tanks, when empty, have a tendency for water ingress. Tanks in the newer shed are pumped out less, as the tank capacity is greater per head of cow, so the slurry will sit in there longer. Tanks under the sheds are not emptied completely until summer, so slurry is not going into the digester fresh.

Slurry from the bottom of the reception tank is pumped into control kiosk and then back again through a top pipe so that slurry is pre-mixed before it feeds the digester. Slurry is then pumped into the digester, with the digester feed pump usually running two minutes in the hour, depending upon the feeding regime.

The digester tank is a single 100mm mineral wool insulated steel glass coated circular tank, gas mixed using an 18 port rotary valve, with mixing pipes distributed across the conical floor of the digester.

The digester is heated with an external heat exchanger. It uses about £200/quarter in electricity, therefore the average estimated use is about 1.25kW per hour. Wesley estimates that this is about the cost that it would take to run the Rayburn.

The digester does not run in summer, but is brought up to temperature when the cows are brought in for the winter.

Trials have been carried out by the Scottish Executive to look at how well the digestion process works, but the farmer was not aware of the results. Wesley noted that Enviro ran some small-scale field tests which highlighted how good the digestate was, but concluded that there was too little of it.

Digestate Use: Output from the digester is pumped into a storage tank which has a mixer. Slurry is then spread onto land using a normal slurry tanker. Digestate is used on the silage fields only. He has cut down on the amount of fertiliser that he uses on these fields, basically not putting any P and only a bit of K, as well as less N. Having the digester has increased his awareness of nutrient management and he is now carrying out more regular soil sampling.

Gas Use: Gas is used to heat the digester and a small amount is used to run a Rayburn cooker in the winter. The Rayburn doesn't run from about May to November, but is a very welcome addition to the kitchen in winter. He did have a boiler to heat the house, but it was difficult to keep the digester temperature up and heat the house, so reverted to Rayburn use only.

Issues with the Installation: Grit from cows' feet ended up in the bottom of the reception tank, so it built up to about 1m, as the stirrer would not agitate it and so it had to be emptied. The only way this could be done was with two vacuum tankers, one putting water in and the other sucking the water/grit mixture. Mr Millar said that if he were doing it again, he would put in a below ground level concrete tank, so a digger could just dig it out at the end of the season.

Legislation, Licensing and Regulation: Because of the Scottish Executive's initiative, the farmer did not encounter any problems in this area.

Record Keeping: Soil sampling is carried out. Initially more digester parameters were logged, including the hours the boiler has been running, but as he has become more familiar with the equipment, the main thing he has paid attention to has been the digester temperature. If the digester temperature is OK, the boiler is running properly and gas is being produced. This digester is run at about 36°C.

Training: Training has been experiential and, as the digester was externally maintained for the first five years, this was not an issue. Much has been learned on maintenance and servicing from local digester maintenance engineer Jamie Gascoigne (Greenfinch/BiogenGreenfinch/Marches Biogas).

Advantages of the Digester: Wesley feels that the grass can use digestate better and faster than normal slurry which can take weeks. He is especially impressed with its use on silage because it can be put on much closer to the cutting date. It can be put on a couple of months before the cutting date and there is no contamination problem. Also, the farm previously had no slurry storage, except for the tanks under the sheds, so the extra storage capacity for the (in this case) digestate was welcome.

Barriers to on-farm AD: Wesley has no major gripes with the digester, but feels that more farmers are unable to take up the technology at the scale of his farm because of the cost, which he estimates to be £200-£250K. He feels that if the farm had several thousand cows kept in all year round, then the figures might possibly stack up better.

10.11 SEC: Brian Smallwood - Corsock Farm

Fast Facts - Corsock Farm



Installation showing input mixing tank on left, control kiosk, digester tank and post store

Digester Size:	80m ³
Digester Type:	As above
Gas Use:	Digester heating.
Commissioned:	2004
Feedstock (T/yr):	Slurry from 260 overwintered cows on slats; 100 cattle in summer
Farm Size:	55 ha, including 29 from remote site
Capital Cost:	£160,000 (estimated by farmer)
Issues:	Some problems with pumps
Barriers to AD:	Cost of plant
Advantages:	Ease of slurry handling, odour reduction, less taint and how well digestate works on the crops.

Farm Type: Corsock Farm is a beef farm which overwinters extra stock. This year, Brian has about 70 sucklers who get about 8T silage per head per winter, as well as 74 Friesian/Holstein getting about 9T. The farm is about 55 ha which includes 29ha on a remote site. Currently about 14 ha are cut for silage on the home farm.

Cows are on rubber mats on concrete.

Digester Description: The digester is on a 50 minute cycle per hour. Slurry is pumped out of the bottom of the mixing tank and back in through the top of the mixing tank. Then, the discharge pump comes in and discharges – all this is done in the first 10 minutes. As soon as it has discharged, the macerator comes in first, then the feed pump comes in and feeds twice in the hour. The system asks for gas and if there is gas, it will burn.

At the time of visit, the digester had a few technical problems, so was just getting back up to temperature and creating enough gas to heat itself. It is heated with its own gas. At the moment whilst still getting up to temperature, the digester is fed about 3m³ per day (measured by using the run time of the pump), but would normally feed at about 4.25 m³ per day.

As with the other Scottish digesters, this one has an external open reception tank with slurry being recirculated and put through a macerator before being fed into the digester at set intervals. Brian doesn't discharge the reception tank below 500, as it contains grit, however the cone of grit is not currently causing problems, i.e. it is not building up on top of outlet.

On advice, Brian removed the macerator cutter head, since the macerator had been blocking up with fibres sticking and he had to take it to bits on a daily basis. Now, it seems to be running well. Digester is mixed using an 8 port rotary valve and heated with external heat exchangers located in the control kiosk. The external heat exchanger pump runs on 50 minutes in the hour. When starting the digester, he heats the slurry up gently, boosting the temperature about 2 degrees per day. He normally runs the digester at 42°C, because he has found that he gets more gas at 42, but after that it tails off, so not much point in running it any higher than that.

He has had an offer of glycerol at a competitive price from a local source, but was unable to take it, so the digester runs on slurry alone.

There are 5 cattle sheds on the farm and tanks under the shed are pumped out and tankered over to the reception tank as required, for example, 2 tanks are cleaned out every week, another down the road is cleared out every 3 weeks, a fourth is pumped out closer to every 4 months and the new slatted shed is pumped out around once a year. Brian notes that the more concrete there is on the farm, the cleaner and better it is to manage, but the more rainwater it catches. Therefore, when it rains a lot, he might have to pump from a tank holding a lot of slurry to one that is holding less. Slurry from the new shed needs water to be mixed into it to get it through the plant, so he dilutes it slightly. Extra silage on the farm is composted.

Although he doesn't do the electricity reading, Brian estimates that the electricity bill is about £260 per quarter @ approximately 18p/kW.

Digestate Use: Brian reckons that one of the great things about the digester is the digestate. For the first three years that the digester was in operation he used no artificial fertiliser. Then he rented out some land 8-9 miles away for silage and it was cheaper to buy artificial fertiliser than to transport digestate with his current tanker. Last year, he hired a 3,500 gallon tanker, but notes that his fertiliser bill, even with today's higher prices, is half what it used to

be. He was paying £140/T for 25:5 and using about 12T. He is now using only 6T, which is spread only on the remote land. No artificial fertiliser is used on the land where his digestate has been spread. Digestate is spread typically in July, September and December, with the silage land at Dalbeattie receiving some in spring and mid-summer.

At the moment, Brian carefully regulates the slurry storage to ensure that there is plenty to keep the digester going throughout the summer. He is considering shutting it down at the end of July and starting it up again in October-November, in order to better time his spreading in line with his storage capacity; for example, this might allow him to spread in July-August-September, with the second spreading occurring around March instead of December.

No trials have been done on the digestate that he is aware of, although he has done some experimental growing of vegetables using the digestate and has been very pleased with the results.

Gas Use: Brian did run a biogas boiler in the house, but the gas destroyed the boiler within 18 months. Additionally, he had to supplement the digester heating with diesel, so it made more sense to use the gas to heat the digester.

Issues with the Installation: There have been problems with hairs in pumps and another pump occasionally needs coaxing to start it. There is grit in the system and this will have to be dealt with but, as Brian philosophically says, “As long as you are scraping concrete, you are going to get grit, as silage effluent will degrade concrete and cows also carry in stones and grit on their feet”.

Legislation, Licensing and Regulation: If the project had not been driven by the Scottish executive, Brian reckons the existence of holiday caravans in the vicinity, as well as local bird sanctuaries, would have added complexity and cost to the project, and he feels objections from these parties may very well have made the project impossible.

Record Keeping: Brian notes down a number of parameters to do with temperatures, levels and running hours every day and can tell when something is amiss in the plant. By doing these readings, he can ascertain whether the feed corresponds with the discharge just by looking on the sheet. He also compares the reading for the day with the one from the day before and keeps an eye on anything that looks like it is getting ‘out of sync’. He will then monitor this for, say, 24 hours to see if it is a ‘blip’ or if he has to do anything about it. He has to come in every day and see if everything is running, so finds it easy to record the figures.

Training: Understandably, Greenfinch didn’t want them to touch certain things whilst the system was under commissioning, but Brian has effectively used Jamie Gascoigne’s maintenance and support visits to help improve his knowledge of the system.

“You can spread [digestate] up to the bedroom window and never get a smell complaint.”

Technical aspects like setting some of the computerised parameters have been a bit of a challenge, but Jamie has been very helpful in ensuring that Brian understands how the system works.

Advantages of the Digester: Brian feels that it is a tremendous system and so simple. He can spread digestate up to the bedroom window and never gets a smell complaint. The digestate makes a big difference on silage and grazing fields, particularly in the short term. If he were using conventional slurry, nothing would graze it for at least a fortnight to three weeks, but this isn't the case with digestate which can be re-grazed much faster.

Barriers to on-farm AD:

Brian feels that he would never have been able to afford a digester, adding, "At 60 years old, how am I going to find £130-£160,000?"

10.12 SEC: Jim Drummond - Castle Farm

Fast Facts - Castle Farm



From l to r: Input tank, control kiosk and (out of picture) digestate storage tank

Digester Size:	About 480m ³ (the largest of the sizes put in)
Digester Type:	As above. 18 port rotary valve.
Gas Use:	Digester heating. Hoped to heat houses with biogas boilers.
Commissioned:	2004
Feedstock (T/yr):	Slurry from about 160 cows plus followers. Maximum input 24T/day
Farm Size:	Dairy 160-170ha, plus another 60 which is rented, set mostly to grass and grass silage
Capital Cost:	£300,000 estimated, includes composting shed
Issues:	Pumps
Barriers to AD:	Cost of plant
Advantages:	Digestate has a better quality than slurry, is easier to spread, doesn't smell and has better value as a fertiliser

When Jim Drummond was approached by the Scottish Executive about the possibility of having an anaerobic digester, the idea of using his slurry to produce gas which could heat his house and his brother's house appealed to him. With kerosene at 16-17p at the time, he

felt it would be cost effective—and has been proved right, with prices this winter reaching peaks of 60-70p or more.

Digester Description: Slurry from the cattle is automatically scraped into a tank at the end of the cow shed, then can be pumped about once a week into the old slurry store or the digester reception tank, both of which are not covered. Jim guesses that the dry matter percentage might possibly be around 10-11%, depending upon rainwater ingress, but adds that if the slurry is too thick, they cannot pump it. In other respects, the principle of the digester operation for this plant is the same as the others. The digester was run throughout the year, using slurry that had been saved in the tanks.

The original estimates for electrical running costs for the digester were about £1000/year, however, it turned out to be around £750 year (@ ~70p/unit), since they were using the cheaper rate through night.

Digestate Use: Part of this particular installation included a compost shed and compost mixer. As the digestate wasn't separated, it would ball up like dough in the mixer, so they would dump it out in windrows using a small trailer so that the machine would then mix it up. The Drummond brothers felt that it would make good compost, but felt that because of the variable input, it could only really be called a soil enhancer. At the end of the day, they felt it was much better used directly on the farm. N, P and K are still supplemented, but less P and K are being used, although Jim felt that this was more a function of the price and not the digestate.

A contractor will come in with an umbilical system to spread the digestate or the Drummonds use a tanker. The contractor prefers to use digestate because it is uniform and works well, as it flows better and does not block the equipment up.

Jim says that he thinks some digestate trials were done, but was not aware of the results.

Gas Use: Gas lines were dug to Jim and his brother's house, but they had problems finding someone to install the boilers, finding that they were either quoted ridiculous prices or the tradesmen simply did not return. Also, the location for one of the boilers was problematic, as it was difficult to put a chimney in. So gas was simply used to heat the digester.

Issues with the Installation: Jim felt that the biggest problem was with the macerator pump, which had a tendency to jam up with such things as ear tags or cow hair. He was also not sure how some of the programmable parameters worked, but was happy that, once he wrote some instructions down, he would be able to do it 'like one of these electronic watches'. Generally, he and his brother felt that the plant ran well.

However, about 18 months ago, a problem with a pump coinciding with the handover of the plant to the farm and a wet season conspired to send the plant into the digester downward spiral of death. This digester output pump was not working well enough to get the normal volume of digestate out of the digester. As it was handover time and whilst trying to solve the problem, they found that gas production fell off. This meant that they could not get enough slurry into the digester and the slurry that they could get in had been watered down because of the wet weather. As gas production fell, digester temperature slowly fell, with the cold watery slurry unable to create enough gas to heat itself. By the time they had recognised the

extent of the problem and realised the knock-on effects, they had lost process and the digester died.

Subsequent cold weather caused further damage to pumps and heating manifolds, but Jim and his brother are planning to get it up and running again and have been discussing with Jamie the best way to do this. They are also looking at a number of possibilities, including getting a poultry unit and using the litter in the digester, although they think that with this particular feed system, they would likely have to water it down or look at the cost of getting a different feed-in system.

Legislation, Licensing and Regulation: No problems encountered due to the nature of the scheme. The farm is not on three phase electricity, so Jim realises that if they wanted to run a CHP, they would likely have difficulties or limitations with grid connections.

Record keeping: As with the other digesters, a number of parameters were noted on a daily basis, although Jim felt that he paid particular attention to the digester temperature, gas production, and whether slurry was going in and digestate was coming out.

Advantages of the Digester: The Drummond brothers were very impressed at what a better product digestate is than slurry. Whilst they hadn't had the chance to use the gas, they pointed out that it doesn't smell when spreading, has good fertiliser value, cattle can graze more quickly after spreading (3 weeks as opposed to 6), there is less taint and less contamination on silage. Ideally, they used to need to spread in January, so that the crop was grazable by April, but SEPA does not allow spreading onto frozen land, so with digestate, they can spread later, but still graze in April. The contractor who drives the silage harvester pointed out that the digestate creates much better grass crops, but Jim is unsure how this could be quantified.

Jim pointed out that there was no crusting in the digestate tank, saying that they used to waste a lot of time and diesel mixing slurry in order to get it into a fit state to spread. He added, "Digestate is no problem, is a good product and does a good job."

Barriers to on-farm AD: Jim felt that even though digestate has a better fertiliser value and he saved himself a lot of time and money dealing with the slurry, unless he was using the surplus gas for heating, it was likely not cost-effective. In any case, he felt that the capital cost of the plant alone meant that he couldn't really recommend it to anybody.

10.13 SEC: Frank Kenyon - New Farm

Fast Facts - New Farm	
	
Digester Size:	About 320m ³
Digester Type:	As above.
Gas Use:	Digester heating. Hoped to heat house with biogas boiler or run CHP
Commissioned:	2004
Feedstock (T/yr):	Slurry from around 200 cows on slats bedded on sawdust.
Farm Size:	308 acres, grass silage, all crop silage
Capital Cost:	Farmer estimated about £250,000, but was unsure

The digester ran for 5 years, with gas being used only to heat the digester. There were some problems with the reception tank recirculation pump which needed to be started manually. Frank felt that there was also a big cost in pumping slurry with tractor across to digester. A second-hand 20kW CHP was installed, but when the heat exchanger pump broke down 3 months later, it caused irretrievable problems with the CHP and repair was deemed uneconomic. He continued to run the digester, but around hand over time 18 months ago, he encountered grit problems within the digester tank itself which caused blockages with the gas mixing and he decided there was no point in continuing to try to run the digester.

10.14 Devon Digester

Fast Facts - Devon Farm	
	
Digester Size:	500m ³
Digester Type:	Single concrete tank, plus a smaller tank for 'cooling off'. Mesophilic, gas mixed with 2 x 36 port rotary valves, 2 internal heat exchangers
Gas Use:	45kW asynchronous CHP, hoping to apply for FITs
Commissioned:	2011 (under commissioning at time of writing)
Feedstock (T/yr):	Mainly grass. Some chicken manure.
Farm Size:	300 acres (121 ha) mixed farm in an NVZ
Capital Cost:	£100,000 (self funded)
Issues:	Still under commissioning, so unknown
Barriers to AD:	Possibly uneconomic at this scale; time will tell
Advantages:	Hope to be able to treat chicken manure, with grass silage as balancing feedstock and earn some income from the feed-in tariff.

The owner of this Devon farm became interested in anaerobic digestion whilst looking for an alternative use for extra grass on the farm. It took about 2 years to investigate the technology and explore the options available. As the owners had experience of construction, they decided upon a cost-effective self-build option, with specialist parts and engineering consultancy provided by Methanogen UK Ltd.

Farm Type: The farm is mainly grass, with beef cattle and free range chickens.

Digester Description: The digester is fed via a feeder wagon and inlet auger. The tank itself consists of an insulated main tank 10m x 10m x 5m, with a smaller holding tank, the whole installation being part set into sloping ground. The tank is heated by 2 internal heat exchangers 2m high and approximately 2m across and gas mixed with 2 x 36 port rotary valves. It is covered with an epoxy coated steel roof as the farmer is experienced in building with these materials.

A biogas boiler heats the digester.

Digestate is augered into a separator, with the liquid fraction going into the smaller holding tank. Gas is held in a bell over water gas holder.

It is too early to tell what the running costs will be.

Digestate Use: Digestate will be used on the grass.

Gas Use: Gas will be scrubbed by injecting a small amount of air, then used in a 45 kW CHP. The farmer is hoping to register for FiTs and has not yet begun the process of attempting grid connection.

Issues with the Installation: Other than those associated with a learning curve, none so far.

Legislation, Licensing and Regulation: None so far.

Record Keeping: None yet, but probably not too many in the future.

Training: Engineering advice and training were bought in from Methanogen but the farmer adds, "Time will tell how much more advice we need".

Advantages of the Digester: The farmer hopes that the plant means that he will be able to recycle nutrients on the farm, provide a largely non-agricultural income from his spare grassland and treat his chicken muck.

Barriers to on-farm AD: Having done investigation into AD, the farmer notes: "AD is something that benefits from economies of scale, but we have tried our best to do it on a very small scale. Time will tell if it has worked. I'm sure there will be things we wished we'd done differently. It's too early yet to decide upon likes and dislikes of the technology."

"I'm sure there will be things we wished we'd done differently..."

11 Glossary of Terms

AD	Anaerobic Digestion, described in this report on page 4
ADAS	An agricultural and environmental consultancy
ADBA	Anaerobic Digestion & Biogas Association
BOD	Biological Oxygen Demand – the oxygen demand that bacteria use whilst decomposing biologically available organic matter. If high BOD organic materials enter a watercourse, they rob the aquatic life of dissolved oxygen during this process
C&I	Commercial and Industrial, referring to wastes from commercial and industrial sites
CAD	Centralised Anaerobic Digestion, described in this report on page 4
CAPEX	Capital Expenditure
CHP	Combined Heat and Power Plant – basically an engine which generates electricity and heat
CSR	Corporate Social Responsibility
DECC	Department of Energy and Climate Change – the UK Government department responsible for tackling UK climate change and UK energy policy
DEFRA	Department for Environment, Food and Rural Affairs – the UK Government department responsible for policy and regulation on the environment, food, farming and rural affairs
Digestate	Digestate is a by-product of the anaerobic digestion process which can be used in liquid form as an effective fertiliser recycling nutrients back to land, and in solid form as a soil conditioner
DM	Dry matter – the dry content of an AD feedstock
DNO	Distribution Network Operators, companies which are responsible for the distribution part of the UK's electricity network, as opposed to the supply
EA	Environment Agency – a UK Public Body responsible for protecting and improving the environment and promoting sustainable development
FGB	Farmgas type 'B' anaerobic digester
FITs	Feed In Tariffs, a UK government incentive to create renewable energy
GIS	Geographical Information System, used to analyse a set of data by geographical region
GHG	Greenhouse gas(es)
GRP	Glass-reinforced plastic (fibreglass), a robust construction material
Ha	Hectare, a measure of land area

Hub and PoD	Hub and Point of Digestion, an innovative model whereby organic substrates which need complex handling and pasteurisation are treated centrally, with the resultant product being sent to distributed anaerobic digesters, either on farm or community digesters
IET	Intelligente Energie Technik GmbH, an Austrian CHP supplier
IRR	Internal Rate of Return, commonly used to evaluate the desirability of making an investment
LECs	Levy Exemption Certificates, an electronic certificate used to demonstrate to HMRC the amount of electricity supplied by a CHP
K	Potassium, used as a nutrient in fertiliser (potash)
KWh	Kilowatt hour – the amount of power consumed/generated over a period of one hour
KWth	Kilowatt thermal – refers to thermal power produced, eg by a CHP
KWe	Kilowatt electric – refers to electrical power produced, eg by a CHP
LSU (or LU)	Livestock Unit, a measure of livestock grazing in agriculture, usually defined as the grazing equivalent of one dairy cow.
MAFF	A former UK governmental department, the Ministry of Agriculture, Food and Fisheries, whose activities are now largely undertaken by DEFRA
Mesophilic	Temperature of AD process operation around 35°C
Mg	Magnesium, used as a secondary nutrient in fertiliser
MPAN	Meter Point Administration Number, a number which uniquely identifies electricity supply points
N	Nitrogen, used as a nutrient in fertiliser
NFFO	Non-Fossil Fuel Obligation, a collection of orders requiring UK DNOs to purchase electricity from the nuclear and renewable energy sectors
NNFCC	National Non-Food Crop Centre, the UK's national centre for biorenewable energy, fuels and materials
NVZ	Nitrate Vulnerable Zone, areas of land that drain into nitrate polluted waters or waters which could become polluted by nitrates. These areas are designated by the EA and are subject to a number of special rules, including slurry storage and spreading times and quantities
Ofgem	The office of Gas and Electricity Markets
PAS110	Publicly Available Specification 110, an industry specification against which digestate producers can verify that they are of consistent quality and fit for purpose
P	Phosphorus, used as a nutrient in fertiliser
ppm	Parts per million

PS	Polystyrene (insulation)
PU	Polyurethane (insulation)
PV	Photovoltaic, a renewable energy technology
QP	Quality Protocol, a protocol which sets out end of waste criteria for the production and use from source-segregated biodegradable waste
RASE	Royal Agricultural Society of England
RDPE	Rural Development Programme for England
REA	Renewable Energy Association
REGOS	Renewable Energy Guarantee of Origin Certificates
RHI	Renewable Heat Incentive, a UK government incentive to promote heat from renewable sources
ROCs	Renewable Obligations Certificates, a certificate issued for eligible renewable electricity generated within the UK
SEPA	Scottish Environment Protection Agency, a Scottish Governmental agency responsible for the protection of the national environment in Scotland
Substrate	An organic feedstock which is fed into an anaerobic digester
T/Yr	Tonnes per year
Thermophilic	Temperatures of AD process operation around 55°C
WAMITAB	Waste Management Industry Training and Advisory Board, a UK company who train and award technical qualifications in the waste industry
WDT	Westray Development Trust, a trust formed on Westray in order to implement some renewable technologies for the island
WRAP	Waste Resources Action Programme
WRI	Waste Refineries International, a UK anaerobic digester company

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