BIOGAS IN LEICESTERSHIRE

Biffa AD Plant, Wanlip

A Technical Feasibility Study for Leicestershire

Anaerobic Digestion – A Renewable Energy Resource

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Executive Summary

●This report follows on from previous work by LCC

●Trial projects in Ayrshire have indicated that single farm plants are not viable

●The Anaerobic Digestion (AD) process creates methane gas that can be burnt to create heat and power, as well as liquid digestate that is an excellent fertiliser and a small amount of fibrous material that can be used as a compost.

●Leicestershire encompasses a considerable resource of animal manure, as well as considerable food waste resources and the potential to grow significant amounts of energy crops. All of these resources are ideal feedstocks for the AD process.

●The analysis of the various options for biogas plants produced the following results:

●On-farm options with up to 600 head of dairy cattle, or 14,000 pigs are not viable

●When food waste is added, the option with 14,000 pigs becomes viable but none of the other on-farm options do.

●A plant fed with a mixture of energy crops and slurry is unlikely to be viable without much enhancement of the grant \ income balance.

●The smallest size of plant that is viable is one of a size sufficient to process the slurry from 3000 cattle + food waste. Even larger plants are even better financially.

●The use of the liquid digestate from AD technology would bring benefits in respect of NVZ controls as well as improved crop yields.

●The use of AD technology is a positive benefit in respect of the current legislative and environmental framework and is positively promoted under the Waste Strategy for England, 2007.

●The proposed “Centre for Excellence” can be procured under the auspices of a Community Energy Company (CEC).

●Such a CEC would be eligible for grant funding from a number of UK and EU sources.

●An ideal site for the “Centre for Excellence” should be an educational institute or a public building that is attracting a high number of visitors.

Conclusion:

An Anaerobic Digestion plant, sized to digest the slurry from the equivalent of 3,000 head of dairy cattle + food waste, would cost approximately **£6million** to build. It should be eligible for 40% grant funding and would be likely to create a **£2.5million profit** over its working life.

It would generate approximately: **3.5 million m^3 of biogas** p.a..
It would generate over: **21 million kWhrs of electricity** p.a.
It would be sufficient to power: **3,500 typical homes**
It would save: **14,000 tonnes of carbon dioxide emissions** p.a.

1.0 Introduction

This study has been initiated by Leicestershire County Council (LCC) to consider the detailed feasibility of utilising the Anaerobic Digestion (AD) process to convert animal and other organic wastes into energy and other useful by-products.

The study considers the application of the technology at the scale of a single farm and at two levels of centralised plant, referred to in the report as Parish scale and Municipal scale. The study also considers the applicability of the process to a dedicated fuel crop as the prime feed source for the process.

2.0 Background to the Study

This study follows on from the scoping study carried out by the Council, which identified the potential for the application of AD technology within the county. The key conclusions of that report may be summarised as follows:

- The viability of on-farm AD will require further study
- A multi-farm approach may be more viable
- The inclusion of other waste streams should be considered

In addition to the work carried out by LCC, there is much world-wide experience of implementing this technology at a wide variety of scales. In the third word, there are many examples of very simple small-scale AD systems that can convert the manure from a handful of animals into sufficient useable gas to fuel the domestic cooking requirement. At the larger scale there are many municipal scale plants throughout Scandinavia, Germany, France, etc., as well as in North America.

Any consideration of the viability of AD technology must be made within the specific framework of the country of deployment, including detailed consideration of energy costs, farming subsidies, legislative constraints, etc.

Whilst the UK has many examples of AD processes used in sewage treatment works, these systems are designed as a means of minimising sewage sludge arisings rather than as waste-to-energy process. The most relevant example of a large scale AD plant being used to convert animal manure into useful energy is the Holsworthy plant in Devon, which has been operational for several years now. The viability of this plant depends on income from “gate fees” but the plant has been located far away from any user for the heat or power generated by the CHPs and hence loses this valuable income stream.

Most recently, a series of on-farm AD pilot plants were installed by The Scottish Executive Environmental And Rural Affairs Dept. onto farms in Aryshire in 2005/6. This project resulted in the installation of 7 AD systems serving farms with 135 – 250 head of dairy cattle and their subsequent monitoring and analysis.

The key conclusions from these 7 projects may be summarised as follows:

- The AD plants worked reliably with minimum farmer input

- The liquid digestate was found to be easier to spread and improved crop yields whilst reducing fertiliser use

- The plants were not found to be economic without financial support

- Significant environmental benefits and energy savings were achieved

Whilst each of these conclusions is of fundamental importance to the present study, it is important to understand the background to these projects, especially when considering the economic findings.

These projects were initiated to improve bathing water quality where the farms are located close to the shore and run-off from muck spreading is causing problems with bathing water quality. None of these projects was initiated in a manner intended to maximise economic performance, but rather the locations and plant sizes were chosen to suit the specific farms that were affected by the bathing water problems.

It is, in large part, the purpose of the present study to consider how the AD process can be implemented in an economically sound manner whilst still bringing all of the known benefits of the technology to Leicestershire.

3.0 The Anaerobic Digestion Process

3.1 Introduction

In the presence of dissolved oxygen, aerobic micro-organisms decompose biodegradable organic matter to Carbon Dioxide (CO_2) and water (H_2O)with release of heat to produce a natural compost process. This is termed an aerobic process.

In the absence of dissolved oxygen, aerobic micro-organisms tend to ferment biodegradable matter to carbon dioxide (CO_2) and methane (CH_4). This mixed gas can be collected and used as fuel. This process is called anaerobic digestion.

Anaerobic digestion occurs naturally wherever high concentrations of wet organic matter accumulate in the absence of dissolved oxygen. This process is common in the bottom sediments of lakes and ponds, in swamps, peat bogs, intestine of animals and in the deep layers of landfill sites.

The principal by-product of this process is methane gas. Man has known about this process for centuries. Methane in marsh gas was discovered during the 18th Century and ideas and experiments have been going on for the last 100 years on how best to use the process.

A natural source of naturally-occurring methane gas is the 'Will-o'-the-Wisp', which is caused by the spontaneous ignition of methane under specific atmospheric conditions as it percolates through mud beneath swamplands or marshlands.

Another source of methane gas production takes place in the stomachs of herbivores such as cattle and sheep (i.e. ruminants). This is an essential process for such animals, as without it they would be unable to digest the grasses they graze on; the anaerobic bacteria present in their stomachs break down the cellulose in the grass into readily absorbable molecules.

An anaerobic digester operates in the same manner as the stomach of such an animal and is essentially a vessel constructed for the purpose of digesting the materials within it (the feedstock).

The gas produced from an anaerobic digestion process is generally described as BIOGAS due to the biological nature of its production. Biogas typically consists of a mixture of carbon dioxide, methane, hydrogen and small proportions of hydrogen sulphide and ammonia. Typical proportions are as follows:

- 60 to 75 % CH_4 (methane)
- 23 to 38 % CO_2 (carbon dioxide)
- approx. 2% H_2 (hydrogen)
- traces H_2S (hydrogen sulphide)
- traces of water

The actual proportions vary with feedstock, operation and design of the process.

3.2 Biological Processes

The overall process of anaerobic digestion occurs through a complex combined interaction between several groups of micro-organism:

Hydrolytic	Break down complex organic wastes into their components sub-units.
Fermentative	Transform these submits into short chain of fatty acids and carbon dioxide and hydrogen.
Syntrophic	Bacteria convert the short chains of fatty acids to acetic acid with release of heat, CO2, and hydrogen.
Methanic	Bacteria produce large quantities of methane and CO2 from acetic acid, and combine the available hydrogen with CO2 to produce more methane.
Sulphate-reducing	Bacteria reduce sulphates and other sulphur compounds to hydrogen sulphides.

The theoretical biogas production can be shown to be 0.35m^3/kg of chemical oxygen demand converted. In practice, yield depends on the composition and biodegradability of the waste feedstock, and its rate of production depends on the population of bacteria, their growth conditions and the temperature of the process.

At ambient temperature, the biogas production is very slow. The rate is greatly increased by operating in the mesophilic temperature range (35-45ºC), or thermophilic temperatures range (50-60ºC). A thermophilic digestion process also reduces the time taken by the process significantly (12-14 days.)

The main reason for the changes in methane production with temperature is understood to be due to the dominance of different bacteria groups which varies with temperature. Difficulties can arise however if the anaerobic process temperature lies between the mesophilic and thermophilic temperature ranges for significant periods as this temperature band suits neither bacteria group and methane production may drop significantly as a result.

3.3 Advantages of Anaerobic Digestion.

The advantages of the anaerobic digestion process for the treatment of organic substances are as follows:

Carbon Neutral:
During combustion, only the CO2 previously fixed by the plants through photosynthesis is released. Thus no fixed carbon is released into the atmosphere (unlike the combustion of fossil fuels).

Pollution Reduction:
Can result in reduction of run-off of manure effluent into the sea and assist with meeting pollution control legislation.

Reduction of Commercial Fertiliser Use:
The recycling of a greater percentage of cattle slurry onto the land in the form of digestate reduces reliance on commercial fertilisers. The digestate has more available nitrogen (typically 25% more) than untreated manure.

Odour Reduction:
The spreading of liquid digestate produces far fewer odours than spreading raw slurry.

Green Energy Production:
Power companies are required to meet ever-more stringent legislation relating to the use of fossil fuels and are now required to purchase energy from alternative energy sources such as biogas powered generation schemes.

3.4 Anaerobic Digestion Processes

A vast array of anaerobic digesters have been developed and placed in operation over the past fifty years. For cattle slurry, the most important factor is whether or not the chosen process can be used to convert the slurry solids to gas while meeting the goals of anaerobic digestion.

The goals of cattle slurry anaerobic digestion are as follows:
1. Generate biogas
2. Produce clean effluent for recycle and irrigation
3. Reduce pathogens associated with the waste
4. Reduce the odours associated with the waste products

Cattle slurry is a semi-solid fluid with much of the energy value stored in the solids. Consequently, the process must be able to convert to gas without clogging the reactor. The process must also be able to handle bedding material, sand and other foreign materials associated with typical cattle slurry. In addition, if cattle slurry is a dilute waste, the process must be capable of mitigating stratification and separation within the reactor.

Inappropriate Processes
A variety of high rate anaerobic processes are <u>not</u> appropriate for digesting cattle slurry. These “high rate” digesters have reduced hydraulic detention times and include anaerobic filters, and a variety of biofilm processes. The bacteria in these processes convert the soluble constituents to gas but have little opportunity to hydrolise and degrade the particulate solids.

These types of reactors tend to clog while digesting cattle slurries and only a fraction of the available energy will be recovered.

Appropriate Processes
The processes that have been used for digesting cattle slurry can be subdivided into high rate or low rate processes. Low rate processes consist of covered anaerobic lagoons, plug flow digesters, and mesophilic completely mixed digesters. High rate reactors include the thermophilic completely mixed digesters, anaerobic contact digesters, and hybrid contact/fixed file reactors.

Anaerobic Lagoons (Very Low Rate):
Anaerobic lagoons are covered ponds. Manure enters at one end and the effluent is removed at the other. The lagoons operate at psychrophilic, or ground temperatures. Consequently, the reaction rate is affected by seasonal variations in temperature.

Since the reaction temperature is quite low, the rate of conversion of solids to gas is also low. In addition, solids tend to settle to the bottom where decomposition occurs in a sludge bed. Little contact of bacteria with the bulk liquid occurs. The biomass concentration is low, resulting in very low solids conversion to gas.

Little or no mixing occurs, and consequently, lagoon utilisation is poor and gas production rates are low and seasonal.

Solids may be screened and removed prior to entering the lagoon, but a considerable amount of energy potential is lost with the removal of these solids. The sole advantage of anaerobic lagoons is low capital cost. The low cost is offset by the lower energy production and poor effluent quality. Periodically the covered lagoons must be cleaned at considerable cost and with considerable odour generation.

Completely Mixed Digesters (Low Rate):
The most common form of anaerobic digester is the completely mixed reactor. Many sewage treatment plants and many industrial treatment plants use a completely mixed reactor to convert waste to gas.

Most completely mixed reactors operate in the mesophilic range. All of the earliest anaerobic digesters used to treat cattle slurry were of this type. The cost of mixing is high, especially if sand, silt, and floating materials, present in the waster stream, must be suspended throughout the digestion period. Some completely mixed reactors operate in a thermophilic range where sufficient heat is available for the thermophilic range of operation.

Most completely mixed reactors are heated with spiral flow heat exchangers. These heat exchangers apply hot water to one side of the spiral and the anaerobic slurry to the other. The spiral heat exchangers have proven to be a successful method of efficiently transferring heat.

Mixing can be accomplished with a variety of gas mixers, the most efficient of which, in terms of power consumed per litre mixed, is the mechanical mixer. Most municipal digesters are intensely mixed to reduce the natural stratification that occurs in a low profile tank. A large amount of evidence has been accumulated over the past 10 years indicating that intense mixing may inhibit the bacterial consortia but, intense mixing is required to keep sands and silts in suspension.

The advantage of the completely mixed reactor is that it is a proven technology that achieves reasonable conversion of solids to gas, and it can be applied to the treatment of cattle slurry. The disadvantage of the completely mixed reactor is the high cost of installation, and the energy cost associated with mixing the digester.

Plug Flow Digesters (Low Rate):
The plug flow anaerobic digester is the simplest form of anaerobic digester. Consequently, it is the least expensive. The horizontal reactor is the most commonly used configuration. The waste enters on one side of the reactor and exits on the other. Since bacteria are not conserved, a portion of the waste must be converted to new bacteria, which are subsequently wasted with effluent. Since the plug flow digester is a growth based system, it is less efficient than a retained biomass system and converts less waste to gas.

Plug flow systems are subject to stratification wherein the sands and silts settle to the bottom and the organic fibers migrate to the surface. The stratification can be partially inhibited by maintaining a relatively high solids concentration in the digester. Periodically, solids must be removed from the plug flow reactor. Since there is no easy way of removing the solids, the reactor must be shut down during cleaning period with considerable cost. Plug flow reactors are normally heated by a hot water piping system within the reactor. The plug flow reactor is a simple, economical system.

Contact Digesters (High Rate):
The contact reactor is a high rate process that retains bacterial biomass by separating and concentrating the solids in a separate reactor and returning the solids to the digester. More of the degradable waste can be converted to gas since a substantial portion of the bacterial mass is conserved.

The contact digester can be either completely mixed or plug flow. It can be operated in the thermophilic or mesophilic range. The contact reactor can treat both dilute and concentrated waste provided the separator can concentrate the digester effluent solids sufficiently to enhance the process. A wide variety of separators have been tested over the past 30 years. Separation requires several days of detention, during which time, the effluent is allowed to separate by gravity in the separation reactor. The digester solids concentration should be less than 2.5% for gravity separation to be used.

Mechanical separation devices have been tested to reduce the detention time required by gravity separation. Centrifuges and other mechanical separators have been used with limited success. These disruptive devices have been shown to inhibit the bacterial consortia and thus limit the effectiveness of the contact process.

Sequencing Batch Reactors (High Rate):
A sequencing batch reactor is a contact digester, which utilizes the same tank for digestion as well as separation. In a sequencing batch reactor the same tank is used to digest the waste and separate the biomass from the effluent liquor Generally, two or more tanks are used, operated in a fill and draw mode. The separation is accomplished by gravity. Consequently, a more dilute, screened waste is treated. Laboratory scale sequencing batch reactors have been used to digest cattle slurry.

Contact Stabilization Reactors (High Rate):
The anaerobic contact stabilization process is a more efficient contact process, previously used for the digestion of both cattle slurry and potato waste. The process has the advantage off efficiently converting slowly degradable materials, which can be degraded rapidly, are digested in the contact reactor.

Hybrid Processes:
A number of hybrid processes have been developed and applied to many different kinds of waste materials. The hybrid processes incorporate a combination of the previously described configurations.

3.5 Control of Pathogens and Weed Seeds

Animal manure represents a potential source of organisms that may be pathogenic to humans.

Animal manure is known to harbour E-Coli, Salmonella, Cryptosporidium, and other pathogens and any use of manure must be closely managed to limit the potential for pathogen contamination.

Bovine Spongiform Encephalopathy (BSE) or “mad cow” disease is a condition of the same type as Kreutz-Jakob in humans or scrapie in sheep. Even though the latter two have been known for some decades, the causal agent was only discovered a few years ago when the danger of BSE became more apparent. The agent is not a microorganism, a fungus or a virus. It is a simple protein named a prion, which cannot even be called an organism.

It is understood that prions are only released from an infected animal’s brain, spinal cord, or eyes. Therefore, prions are understood not to be excreted in animal manures. As a result, digesters using manure or other agricultural feedstocks are not likely to be affected by the BSE problem.

An issue of some importance to the farmers is the re-cycling of weed seeds that might occur with the spreading of the digestate and fibre onto the land. The pasteurisation temperatures used to kill pathogens are sufficiently high as to ensure that all weed seeds will be killed. This should result in a significant saving to the farmers by avoiding the need for weed controls as a result of slurry spreading activities.

3.6 Control of Odours

Manure odours are caused principally by intermediate metabolites of anaerobic decomposition. It has been found that if odorous compounds are confined within the digester medium, many of the intermediary odorous compounds will be metabolised to less odorous compounds or to lower concentrations.

Anaerobic digestion, by its very nature converts, odour-causing materials in organic matter to methane and carbon dioxide, which are odourless. Generally, that which smells offensive is the prime food source for methane-producing bacteria.

Most properly operated anaerobic digesters will eliminate the generation of odours from the site. Plug flow anaerobic digesters and the anaerobic lagoon must be periodically cleaned. During the cleaning process odours are generated.

Thermophilic completely mixed reactors produce an effluent that is far more odorous than mesophilic reactors. Contact and completely mixed digesters significantly reduce odours and may not require cleaning, especially if refractory inorganic and organic solids removal is practiced.

4.0 Waste Resources in Leicestershire

An AD plant is capable of digesting a very wide range of feedstocks. In principle, any material that will rot when left lying in the open air can be used as a feedstock. Such materials are referred to as being “putrescible”.

Putrescible wastes can be divided into a number of basic categories relating to how the materials are produce and treated.

Whilst the main focus of this report is animal derived wastes, particularly cattle slurry, it is also possible to consider the use of each of the following materials in conjunction with the animal manure. The manure is an essential part of any process because it contains a wide range of bacteria necessary to foster the digestion process, but it is also considered the most likely feedstock because it is a waste product with little, or even negative, value and its disposal by traditional spreading methods brings problems with odours and ground contamination.

The slurry produced by dairy cattle is a particularly suitable feedstock because these animals are typically kept indoors for up to 6 months per year and their manure must be collected and disposed of. The manure produced by beef cattle, by contrast, is generally deposited directly onto the pasture by the animal and is not worth collecting.

Pig and poultry farms also have large quantities of manure deposited indoors and this material is also suitable for use in an AD plant, though poultry manure (litter) contains a very high proportion of ammonia products and can be difficult to digest without risk of damage to the digestion process.

4.1 Municipal Putrescible Waste

This material is the organic fraction of household and commercial waste and can include such materials as vegetable peelings and left-over food waste. Because this material has not already been digested by an animal, it has a far higher “energy content” than manure.

Mixing a proportion of such material with animal slurry will greatly enhance the methane production, and hence the viability of the plant.

Most of this material, and nearly all from household sources, is collected by local authorities and treated \ disposed of on a municipal scale. Leicester produces about 140,000 tonnes of municipal waste per annum with about 45,000 tonnes of this being organic material that can be treated by and AD process or by composting. An existing contract is in place with a private waste contractor to deal with these municipal waste arisings including an AD plant located within a water treatment plant.

It is generally not feasible to access this waste stream as a result of the long-term commitments and contracts entered into by most local authorities.

Having said that, it is entirely possible for a producer of waste, either domestic or commercial, to collect the organic fraction of their waste arisings and deal with them in some other fashion than “putting it in the bin”. A very common example of such action is the domestic composting bin where keen gardeners will ensure that their domestic putrescible wastes are collected separately from their other waste and deposited into a composting bin for use on the garden or allotment.

Most commercial producers of organic wastes will have already sought out means of disposing of these wastes that avoid the costs of having the local authority dispose of them on their behalf. During the course of the present study it has become very apparent, for example, that the several cheese producers in Leicestershire dispose of most of their whey waste arisings for pig feed. Whilst this material would be an ideal feedstock for an AD process, it would not be wise to assume that the plant will need to intercept this waste flow and thus result in a “bidding war” to gain access to the waste. We have already determined that the pig producers in Leicestershire would be unhappy to lose this source of feed for their animals, especially since the pig farmers are paid to remove the material from the factories .

The best option for accessing the putrescible waste stream would, therefore appear to be to consider taking the arisings from such as commercial kitchens which are part of the site on which an AD plant is located. In the case of an on-farm unit, this would likely be domestic kitchen arisings only, whereas in the case of a Parish or Municipal scale plant, this would be the arisings from the site upon which the plant is located (see later).

4.2 Human Sewage Sludge

The disposal of sewage sludge from sewage treatment works is a matter of increasing difficulty for local authorities. Disposal at sea was once a favourite option but this is now forbidden while disposal onto land is being made ever more difficult by increasingly stringent regulations.

Although this material might seem to provide many benefits as a feedstock, there are so many regulations governing the transport and handling of human sewage as to make this option very unattractive. Furthermore, the possibilities for transferring disease across the food chain make it very difficult to consider the disposal of the liquid and fibre digestates that have been derived from human sewage sludge.

For the purposes of the present study, we have excluded this material from further consideration, assuming that the local authorities can make their arrangements within the confines of their sewage treatment works.

4.3 Fuel Crops

In addition to waste materials which would be expected to form the majority of the feedstock for an AD process, it is equally possible to consider the digestion of organic materials that have been grown specifically for use in this process.

Such fuel crops could form a small percentage of the total feedstock and be used to enhance the methane production form animal wastes, or could also be the main constituent of the feedstock with a small percentage of manure used to provide the digestive bacteria that the process needs.

During the course of this study we have discovered a current proposal to build AD plants designed to use primarily maize as a feedstock since this produces the highest energy yield. The developers of this proposal intend that such plants could be built on agricultural sites in close proximity to the fields that would be used to grow the feedstock. Such a proposal would need to be proven viable on the basis of electricity sales alone (see later).

4.4 The data set derived from extensive investigation into the County's waste resources is presented on the following spreadsheets and is then presented graphically on the following four maps.

The maps show the county of Leicestershire split into four areas:

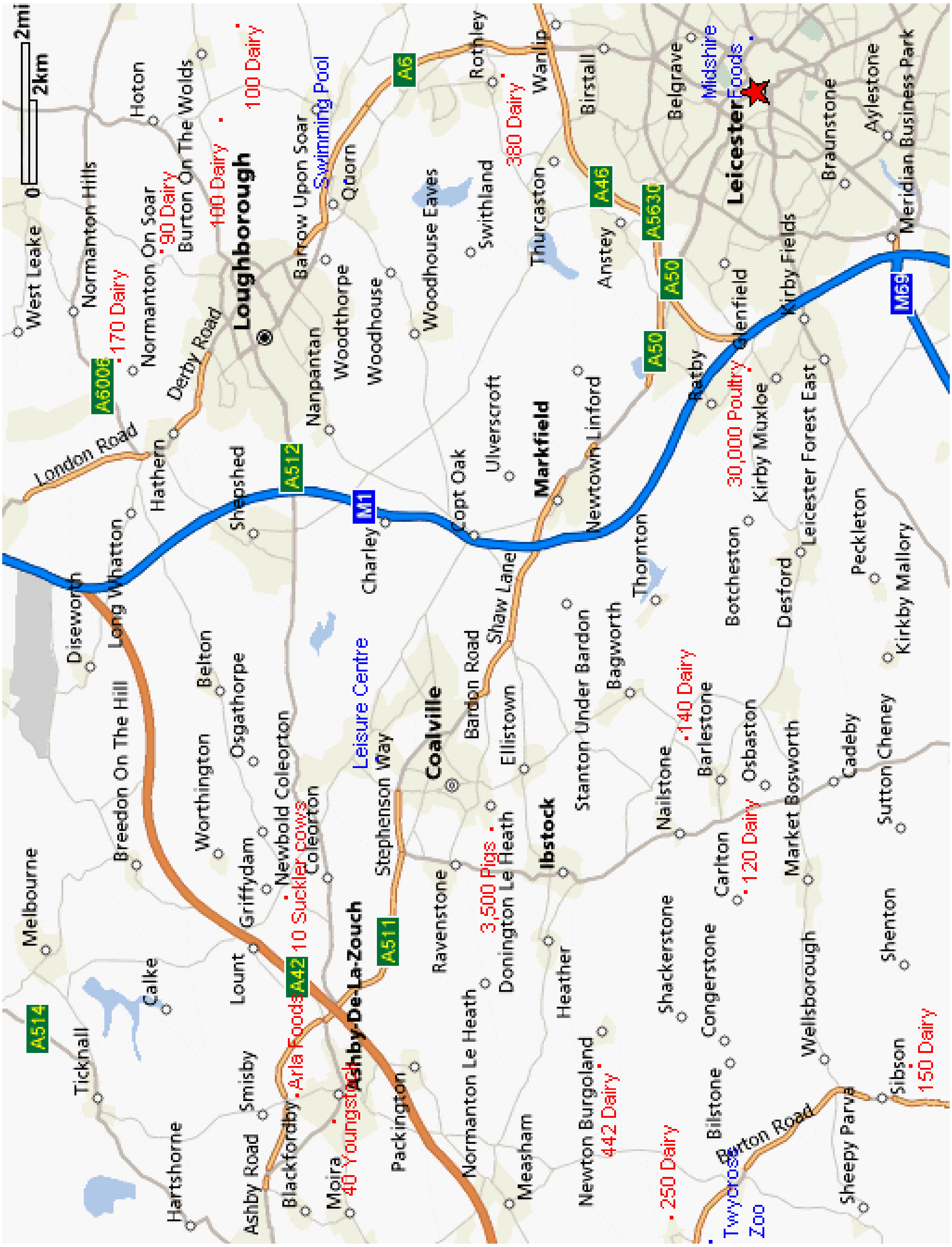
- Loughborough
- Lutterworth
- Melton Mowbray
- Market Harborough

On each of these maps is marked (in red) the locations and sizes of animal husbandry units that have shown a positive interest in being involved in the proposed AD projects.

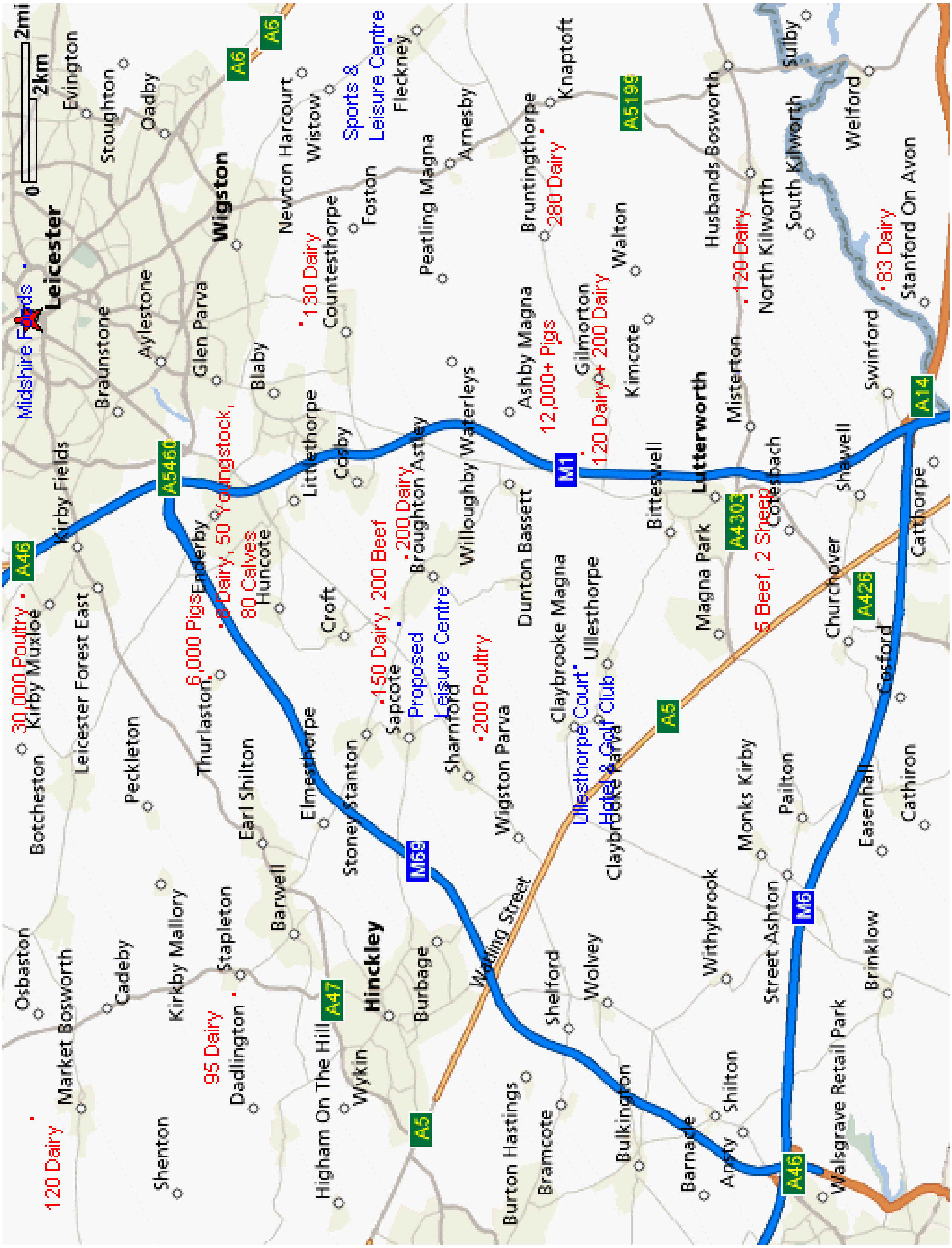
Also marked on the maps (in blue) are locations of various relevant locations such as food producers, possible AD sites and the specifically mentioned locations of Brooksby College and Twycross Zoo.

Following each map is a Geographical Analysis sheet which identifies the distances between the waste resources and the nearest amenity sites that have been identified. (Note: No analysis is presented for Market Harborough Area, as no available resource has been identified in this area)

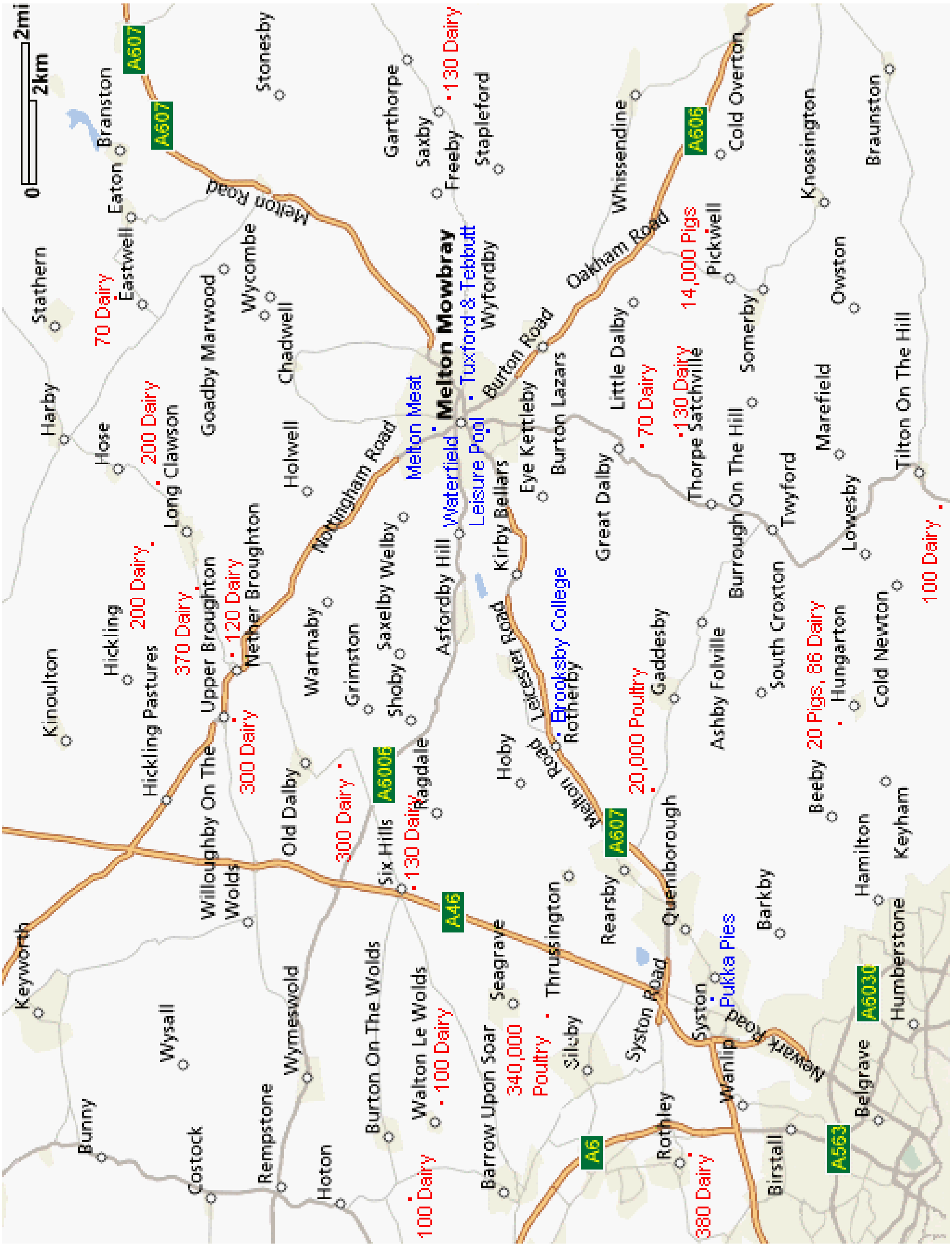
LOUGHBOROUGH AREA



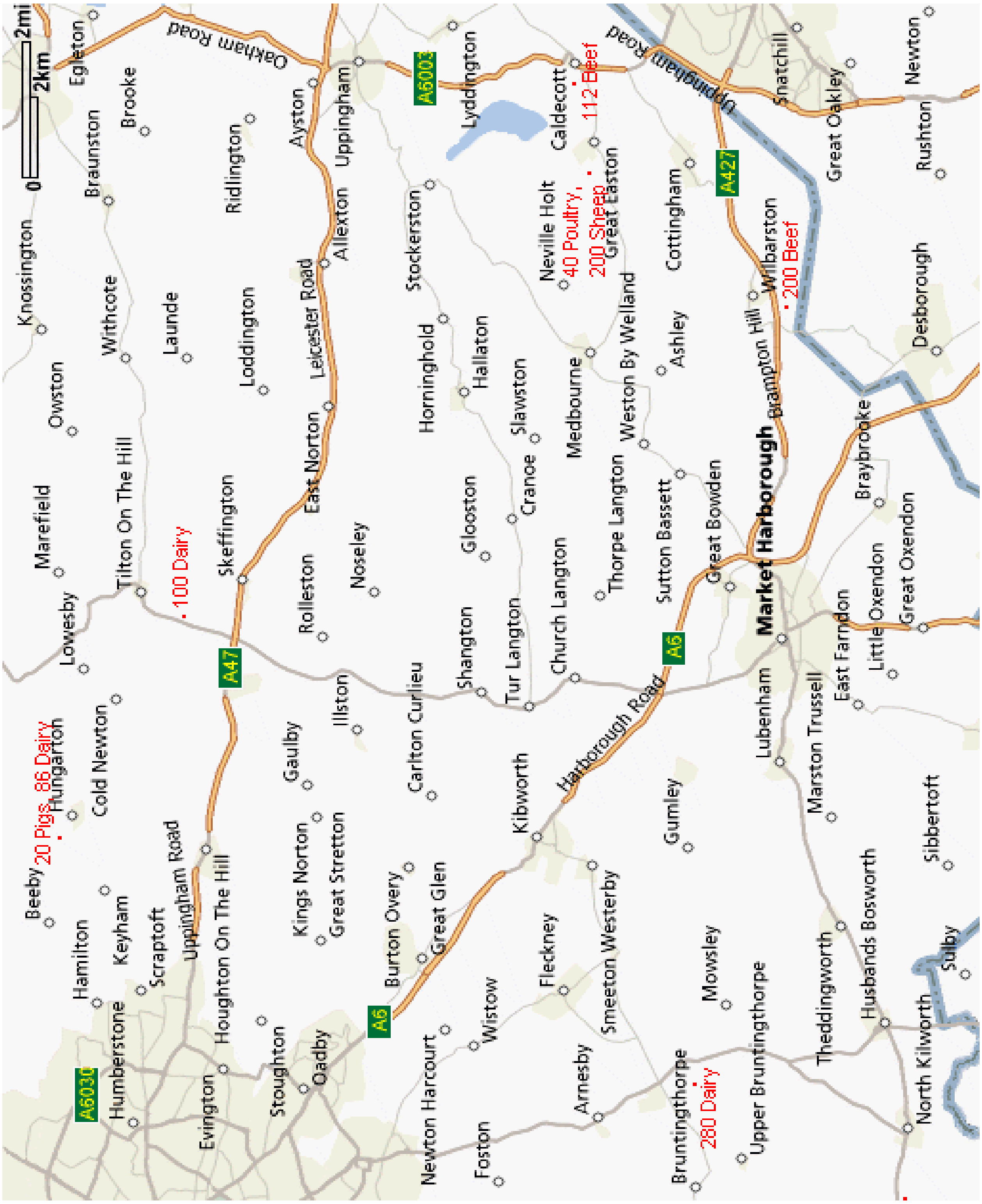
LUTTERWORTH AREA



MELTON MOWBRAY AREA



MARKET HARBOROUGH AREA



5.0 Utilisation of Digestion Products

The Anaerobic Digestion process creates biogas, fibre and a liquid by-product. The balance of the different products from AD is shown below.

Biogas	2 – 4%
Liquid digestate	5 – 23%
Fibrous material	73 – 91%

5.1 Biogas

The biogas produced in the digester is primarily composed of methane (approximately 60%) and carbon dioxide (approximately 40%), with traces of hydrogen sulphide and ammonia. The quality of the feedstock used in the digester will determine how much gas is produced and its constituents.

The biogas produced through the AD process usually needs to be cleaned after generation as the gas contains corrosive elements that may damage CHP engines.

Up to one third of the biogas energy will be needed to sustain the heat in the digester; the remaining two thirds will be surplus and can be put to various uses:

- The gas can be burned to generate heat, either on site or piped elsewhere.

- The gas can be used as fuel for an engine connected to a generator to produce electricity which can then be used on site, marketed to the grid and to other networks.

- If a combined heat and power (CHP) plant is used, all gas will be consumed to provide both electricity and heat. This is more efficient use of the available energy; the whole digester heat requirement is normally provided from the heat recovered from the engine and exhaust gas.

- It is also possible to use the gas (if carbon dioxide is removed through the use of water towers, and the gas is compressed), to run motor vehicle engines, which would need to be converted to use the gas. The processes to clean and compress the gas for this purpose, and the conversion of the vehicles, are expensive, but becoming more viable as fuel prices rise.

5.2 Liquid Digestate

The digestate which remains after the gas has been removed is pumped to a storage tank, after which it can be spread directly on to the land. However, this digestate can only be considered partially treated at this stage, and should be stored ready for applying to the farm land at the appropriate rate (see MAFF Code of Good Agricultural Practice for the Protection of Water, as well as specific guidelines in Nitrate Sensitive Areas and Nitrate Vulnerable Zones). Alternatively, the digestate can be separated into fibre and liquid.

The liquid from the AD process has a low level but diverse range of nutrients. It can be used as a liquid fertiliser in a planned fertiliser regime. The liquid is generally used on the farms on which it was produced. Spreading and application methods for the liquid depend on the type of crop being grown. As with any fertiliser containing nitrogen, the liquid should only be used on actively growing crops, in certain locations and on certain types of soil.

The liquid should be applied as part of an integrated fertiliser programme to ensure that the optimum nutrient requirements for the crop are supplied. It is good practice for the farmer or operator to regularly analyse the soil, and the AD liquid, to assess the appropriate application rate, and to quantify the amount of chemical fertiliser to be applied to crops and grassland. Liquid can be stored on the farm, or at the CAD plant, in lagoons or large tanks, If possible, these should be located adjacent to the areas where the liquid will be applied.

While it is still warm, the liquid will continue to produce small amounts of methane. Once stored, the sediment in the liquid will settle, so it will need to be stirred or agitated to ensure uniformity throughout before application or transporting. It is possible to use the same tankers which have delivered the feedstock to export liquid digestate.

The application of the liquid digestate to the land can be carried out with much greater regularity than would be the case with raw slurry. Discussions with farmers involved in such plants reveals a unanimous desire for more of the liquid digestate than they presently have available.

When raw slurry is spread on the land, the cattle cannot be grazed on that land for a period of up to 6 weeks due to the presence of the dried slurry cake at the roots of the grass. By contrast, cattle can be put back onto the grassland the day following application of liquid digestate. This means that a far higher rate of application can be made through the year, with associated benefits in terms of the number of units of fertiliser needed to be supplied from commercial fertilisers. The cost savings to the farmers will be substantial.

5.3 Fibrous Material

The fibre produced from AD is bulky and contains a low level of plant nutrients. It can be used as a soil conditioner, and the most efficient use for the fibre is to return it directly to the land locally. This is much easier to do after processing than conventional land-spreading as spreading the fibre requires much less power and can be done using a small tractor rather than specialised equipment. It is also much less offensive to neighbours, having no odour after digestion.

AD fibre can be used to condition the soil, and as low grade fertiliser. In some cases the fibre from AD can be used as an alternative to peat, although it does not have exactly the same purpose as peat (which is nutrient-free).

A possible strategy for increasing the value of the fibre is to further compost it aerobically after processing to produce a potting compost/growing medium. This process can be speeded up through careful management and control such as adding heat or insulating the composting bins. However, market development is required to make the commercial sale of the fibre viable on any large scale. For any sale of fibre, access to local markets is crucial as it would not be economically viable or environmentally sound to transport it long distances.

Storage facilities will be needed for the processed fibre. The market is seasonal, so storage could be needed for up to six months output. Stored fibre will continue to compost aerobically, so it will need to be carefully managed and controlled, using methods such as stabilising through further composting. Fibre needs to be stored under cover to prevent rainwater getting in. Flies may also be a problem around stored fibre, so siting storage facilities will need to take that into account.

6.0 On-Farm Options

Perhaps the most obvious place to install an AD plant to process animal waste is on the farm where the waste is produced. This would also have the benefit of creating the shortest possible transport distances for delivery of the slurry and disposal of the digestate.

It is, however, very unlikely that this arrangement will produce an economically viable plant as recent experience with the seven Ayrshire on-farm AD plants has proven

The fundamental problem with most on-farm locations is the lack of demand for the power and the heat generated by the CHP. If there is no on-site demand for the power generated, this can be sold back to the grid but the sale value of the power will almost certainly be less than the farm is paying to buy power from the grid, so the total value of the power is less. Any electricity generated by such a system would qualify for Renewable Obligations Certificate (ROCs) from central government. These certificates can be sold on the Ofgem market at a value which depends on the supply \ demand within the marketplace but is typically around 4-4.5p/kWhr. Whilst the value of the ROCs is independent of whether the power is used on site or sold to the grid, the total value of power generated is <u>either</u> the sale cost + ROC <u>or</u> power purchase cost avoided + ROC:

Typical sale price to grid @ 4p + ROC value @ 4.5p = 8.5p total value
Typical grid purchase cost @ 7p + ROC value @ 4.5p = 11.5p total value
From this simple calculation it can be seen that the income from power generation will be some 25% less if the power has to be sold to the grid.

The heat generated only has a value if it can be used on the farm to displace other forms of heating, or it can be sold to a third party. Most farms have very little demand for heat, other than for heating of the farmhouse and this demand will be intermittent and seasonal. The cost of heat is only about 3.5p/kWhr but it should be well noted that a CHP engine will produce twice as much heat as it does power, making the potential income from the sale of heat almost as valuable as the income from the sale of power to the grid. For a typical farm to derive any financial benefit from the heat generated, it would be necessary for the farm to have an on-site operation such as a range of heated greenhouses where fossil fuel consumption could be displaced. From our survey work for this report, we did not find this to be the case on any of the respondent’s farms.

We have carried out a series of analyses of On-Farm options as follows. The numbers of animals have, in each case been chosen to represent a single small farm (130 cattle); a single larger farm (300 cattle) and a pair of larger farms (600 cattle) as these seem to be the most typical sizes.

Case 1:	On-farm:	130 dairy cattle
Case 2:	On-farm:	300 dairy cattle
Case 3:	On-farm:	600 dairy cattle
Case 4:	On-farm:	14,000 pigs
Case 5:	On-farm:	130 dairy cattle + food waste
Case 6:	On-farm:	300 dairy cattle + food waste
Case 7:	On-farm:	600 dairy cattle + food waste
Case 8:	On-farm:	14,000 pigs + food waste

It will be noted that most of the above analysis is based on the slurry generated by dairy cattle but it is very important to note that much of the dairy cattle in Leicestershire are kept on straw bedding so no slurry is generated. Instead, a large quantity of mixed manure and straw is created, which is typically stored in dungsteads or pits outdoors.

We also provided a comparison with straw bedded units in Case 1.

Case1a: On-farm: 130 dairy cattle

The outcome of the analysis is presented in Appendix 1 but is summarised as follows. The values in the following table are presented at Low, Medium and High expectations of outcomes. Whilst the report will focus on the medium expectations, the other values can be used to ascertain the sensitivity of the calculations to changes in the variables such as gas production rates and interest rates.

It is assumed that all of the electricity generated will be sold to the grid with a value of 4p/kWhr + 4.5p/kWhr for ROCs. It has also been assumed that the digestate will be used on the farm and that most of the heat generated will have zero value.

Case 1: 130 dairy cattle slurry

This represents the smallest farm unit that was considered worthy of analysis and represents a significant proportion of the dairy cattle units in Leicestershire.

	Low	**Medium**	**High**
Tonnage of feedstock\day	5.2	7.2	9.1
Biogas/day (m³)	72	243	390
Electricity generated/day (kWhrs)	399	1453	2800
Capital Cost of plant:	£752k	£885k	£1,006k
Life cycle operating profit/loss	-£1,162k	-£1,256k	-£1,303k
Profitability index	(-)	(-)	(-)

Case 1a: 130 dairy cattle manure + straw

This represents the same farm unit as considered in Case 1 but uses slightly different feedstock properties to represent the locally common farm practice of bedding the dairy cattle on straw

	Low	**Medium**	**High**
Tonnage of feedstock\day	10.2	12.2	14.1
Biogas/day (m³)	60	243	390
Electricity generated/day (kWhrs)	331	1453	2800
Capital Cost of plant:	£1,058k	£1,162k	£1,253k
Life cycle operating profit / loss	-£1,670k	-£1,682k	-£1,685k
Profitability index	(-)	(-)	(-)

<u>Conclusion 1:An on-farm unit with 130 cattle will yield very large losses over the plant life cycle. The addition of straw bedding makes the losses greater as the plant size must be greater to handle the increased tonnage of material and the water needed to restore the correct solids content in the feedstock.</u>

Case 2: 300 dairy cattle slurry
This represents the larger farm units and also represents a significant proportion of the diary cattle units in Leicestershire.

	Low	Medium	High
Tonnage of feedstock\day	12.0	16.5	21.0
Biogas/day (m³)	187	562	900
Electricity generated/day (kWhrs)	105	3354	6459
Capital Cost of plant:	£1,157k	£1,370k	£1,567k
Life cycle operating profit / loss	-£1,725k	-£1,808k	-£1,776k
Profitability index	(-)	(-)	(-)

Case 3: 600 dairy cattle slurry
This represents two of the larger farm units operating together and assumes that the farms are located close together (within 5km).

	Low	Medium	High
Tonnage of feedstock\day	24.0	33.0	42.0
Biogas/day (m³)	375	1125	1800
Electricity generated/day (kWhrs)	2070	6708	12919
Capital Cost of plant:	£1,666k	£1,985k	£2,282k
Life cycle operating profit / loss	-£2,846k	-£2,834k	-£2,598k
Profitability index	(-)	(-)	(-)

Conclusion 2: A pair of farms with 600 cattle between them will yield very large losses over the plant life cycle. The losses are relatively greater than a single farm unit because of increased transport costs.

Case 4: 14,000 pigs
This represents either of two large pig breeding units that were discovered by our survey work. One of these units is already considering the installation of an AD plant to consume all of the pig slurry plus certain other commercial wastes. It has been assumed that the piggery will not be able to make use of the heat generated by the CHP.

	Low	Medium	High
Tonnage of feedstock\day	42	98	154
Biogas/day (m³)	1066	1599	2132
Electricity generated/day (kWhrs)	6237	11,473	17,651
Capital Cost of plant:	£2,270k	£3,574k	£4,562k
Life cycle operating profit / loss	-£2,688k	-£4,000k	-£4,706k
Profitability index	(-)	(-)	(-)

Conclusion 3: None of the manure-only systems will be able to operate profitably. To achieve profitability, it will be necessary to consider further measures such as the inclusion of food wastes or fuel crops and/or the sale of heat & power on site.

Case 5: 130 dairy cattle slurry + food wastes

This is the same as Case 1 but assumes the addition of 1 tonne per day of generic food waste with a gate fee of £45 per tonne and 1 tonne per day of water to provide acceptable solids content.

	Low	Medium	High
Tonnage of feedstock\day	7.2	9.2	11.1
Biogas/day (m^3)	143	404	605
Electricity generated/day (kWhrs)	793	2513	4348
Capital Cost of plant:	£890k	£1,010k	£1,122k
Life cycle operating profit / loss	-£1,140k	-£1,150k	-£1,129k
Profitability index	(-)	(-)	(-)

Case 6: 300 dairy cattle slurry + food waste

This is the same as Case 2 but assumes the addition of 2 tonnes per day of generic food waste with a gate fee of £45 per tonne and 1 tonnes per day of water to provide acceptable solids content.

	Low	Medium	High
Tonnage of feedstock\day	15.0	19.5	24.0
Biogas/day (m^3)	312	883	1331
Electricity generated/day (kWhrs)	1724	5470	9553
Capital Cost of plant:	£1,304k	£1,506k	£1,696k
Life cycle operating profit / loss	-£1,497k	-£1,413k	-£1,255k
Profitability index	(-)	(-)	(-)

Case 7: 600 dairy cattle slurry + food waste

This is the same as case 3 but assume the addition of 4 tonnes per day of generic food waste with a gate fee of £45 per tonne and 3 tonnes per day of water to provide acceptable solids content.

	Low	Medium	High
Tonnage of feedstock\day	3.10	40.0	49.0
Biogas/day (m^3)	624	1766	2662
Electricity generated/day (kWhrs)	3499	10941	19106
Capital Cost of plant:	£1,916k	£2,219k	£2,508k
Life cycle operating profit / loss	-£2,325k	-£1,973k	-£1,147k
Profitability index	(-)	(-)	(-)

Case 8: 14,000 pigs + food waste

This is the same as case 4 but assumes the addition of 15 tonnes per day of generic food waste a gate fee of £45 per tonne. No additional water is required to provide acceptable solids content.

	Low	Medium	High
Tonnage of feedstock\day	57	113	169
Biogas/day (m^3)	2080	3569	4576
Electricity generated/day (kWhrs)	11855	24701	35558
Capital Cost of plant:	£2,693k	£3,919k	£4,882k
Life cycle operating profit / loss	+£345k	+£436k	+£570k
Profitability index	0.18	0.16	0.17
IRR	8.3%	8.0%	8.1%

Conclusion 4: The addition of food waste to the animal wastes has a profound effect on the economics of the systems. The additional income from the gate fees charged for the disposal of the commercial wastes, plus the additional gas production, creates better income for the operator of the plant. Nonetheless, it is only when the plant is scaled up to the Case 8 size that it is possible to create a positive profit over the life cycle of the plant.

During the course of our survey work we became aware of a Leicestershire company proposing to build AD plants as an on-farm option but using mostly fuel crops (maize) as the feedstock mixed with approximately equal quantities of manure to provide the necessary bacteria. This company are proposing that the biogas generated is used to create electricity for sale to the grid and intend that the process sho8uld be viable on that basis.

Case 9: On- farm:Fuel Crop

This case is based on using the slurry from 300 dairy cattle mixed with15 tonnes per day of fuel crop and 20 tonnes per day of water to provide acceptable solids content.

	Low	**Medium**	**High**
Tonnage of feedstock\day	47	51	56
Biogas/day (m³)	1727	2679	3312
Electricity generated/day (kWhrs)	9537	17370	23767
Capital Cost of plant:	£2,415k	£2,569k	£2,714k
Life cycle operating profit / loss	-£2,764k	-£2,108k	-£1,583k
Profitability index	(-)	(-)	(-)

This calculation shows a major discrepancy between the calculated profitability (£2.5million loss) and the intention of the developers to produce a viable plant to process this material.

We have carried out further analysis of this concept to ascertain how our calculations could return a positive result and have discovered that this can be achieved by the following means:

Reduce capital investment to around £500,000:

This could be achieved in practice by reducing the actual build cost to around £1,000,000 instead of the £2,500,000 estimate, or by assuming capital grant funding of 80% rather than the 30% used elsewhere in this report. The proposers of this plant base their calculations on a build cost of around £1.0million and assume 50% grant funding.

Reduce the running cost allowance:

The calculations we have done have assumed a certain number of dedicated staff to operate the project, derived from the sizes of the various plants. If we assume that the manpower will be provided by presently-employed farm staff, we can reduce the running costs by a significant margin. Reducing total life cycle running costs from £2.2million to £1.5 million is sufficient, in this case, to provide a viable plant on highest expectations.

Increase the size of the plant:
We have calculated that the plant would have to be scaled up by a factor of about seven to create a fully viable proposal . At this scale the digester would need some 90 tonnes of fuel crop per day + 100 tonnes of water per day, with a capital cost of the order of £6,000,000.

Conclusion 5: The concept of a fuel crop digester that only earns income from the sale of electricity to the grid is difficult to reconcile with our calculated results. Whilst it may be possible to do this, there are many negative factors that are easily overcome by the other cases studied.

7.0 Centralised Options

Having considered the factors that affect the viability of the various on-farm options we now must consider whether there are factors that might make an off-farm option more viable.

The factors that may be considered differently for these cases include the following:

- ●Potential for sale of electricity on-site giving better value for electricity generated.
- ●Potential for sale of heat on-site giving an additional income stream
- ●Increased feedstock and digestate transport costs
- ●Economies of scale related to increased digester size to deal with the arisings from groups of farms.

To provide best comparisons for these cases we have split them into two size groups, referred to as “Parish Scale” and “Municipal Scale”

7.1 Parish Scale Systems

Case 10: 1,500 cattle slurry

This is the smallest scale of AD system we could consider as a “parish” scale installation, dealing with the waste arisings from 5 -10 farms and returning the liquid digestate to those farms at no cost. We have assumed that the chosen location would buy all of the electricity and heat generated.

	Low	**Medium**	**High**
Tonnage of feedstock\day	60	83	105
Biogas/day (m^3)	938	2813	4500
Electricity generated/day (kWhrs)	5176	16770	32298
Capital Cost of plant:	£2,722k	£3,273k	£3,796k
Life cycle operating profit / loss	-£-4,335k	-£2,723k	-£95k
Profitability index	(-)	(-)	(-)

Case 11: 3,000 cattle slurry

This is a typical scale of “parish” AD system, dealing with the waste arisings from 10 -20 farms and returning the liquid digestate to those farms at no cost. We have assumed that the chosen location would buy all of the electricity and heat generated.

	Low	**Medium**	**High**
Tonnage of feedstock\day	120	165	210
Biogas/day (m^3)	1875	5626	9001
Electricity generated/day (kWhrs)	10352	33540	64596
Capital Cost of plant:	£3,970k	£4,813k	£5,629k
Life cycle operating profit / loss	-£5,384k	-£2,103k	+£3,285k
Profitability index	(-)	(-)	0.83
IRR			12.7%

Conclusion 6: The smallest scale of plant that is financially sound is around 3000 head of cattle, or equivalent. The economics of such a plant, however are acceptable at only the highest expectation.

Case 12: 3,000 cattle slurry + food waste

This is the same as case 11, but includes an additional tonnage of food waste to supplement the slurry and enhance gas production. This case assumes that no gate fee is charged for the incoming food waste.

	Low	**Medium**	**High**
Tonnage of feedstock\day	163	208	253
Biogas/day (m³)	3439	9645	14399
Electricity generated/day (kWhrs)	18983	60057	103329
Capital Cost of plant:	£4,731k	£5,587k	£6,417k
Life cycle operating profit / loss	-£4,787k	+£2,350k	+£9,917k
Profitability index	(-)	0.60	2.21
IRR		11.5%	16.1%

Case 13: 3,000 cattle slurry + food waste + gate fees

This is the same as case 11, but includes an additional tonnage of food waste to supplement the slurry and enhance gas production. This case assumes that a minimal gate fee of £5 per tonne is charged for the incoming food waste. This is representative of the “salt whey” that is produced by the dairy product manufacturers for which they presently pay £6 per tonne for disposal.

	Low	**Medium**	**High**
Tonnage of feedstock\day	163	208	253
Biogas/day (m³)	3439	9645	14399
Electricity generated/day (kWhrs)	18983	60057	103329
Capital Cost of plant:	£4,731k	£5,587k	£6,417k
Life cycle operating profit / loss	-£4,263k	+£2,873k	£10,440k
Profitability index	(-)	0.73	2.32
IRR		12.2%	16.3%

Conclusion 7: The addition of food waste is key to the profitability of an AD plant of this scale. The inclusion of gate fees has very little impact on the overall costings as the gas production improvement is the main positive factor.

7.2 Municipal Scale

Case 14: 12,000 cattle slurry

This case represents the largest AD plant that could be envisaged for Leicestershire. To make such a plant feasible it would be necessary to find a location with excellent road links and a site with very large energy demands to permit sale of the power and heat on-site.

	Low	**Medium**	**High**
Tonnage of feedstock\day	480	660	840
Biogas/day (m^3)	7501	21901	34172
Electricity generated/day (kWhrs)	41407	130566	245219
Capital Cost of plant:	£8,564k	£10,612k	£12,654k
Life cycle operating profit / loss	-£10,292k	+£3,921k	+£23,771k
Profitability index	(-)	0.53	2.68
IRR		11.1%	16.7%

Conclusion 8: At this scale, the plant can be seen to be viable, producing similar expectations of returns as Case 12. The additional difficulties associated with delivering a project of this scale make it less attractive than the smaller Parish scale cases.

8.0 Waste Disposal Implications

8.1 Disposal of Wastes

There are three quite distinct aspects to waste disposal that relate to this project. On the one hand there are the existing arrangements for the collection and disposal of the various types of municipal waste generated within Leicestershire including:

Domestic waste:	typically collected by kerbside collection vehicles
Recycled waste:	glass, paper and metal deposited in recycling bins
Commercial waste:	typically disposed of to landfill
Organic waste:	often disposed of to agriculture

The total tonnage of this waste stream is approximately 14,000 tonnes per annum, with that vast majority of this amount (c. 100,000 tonnes) being delivered to the waste treatment plants in a mixed form. This material is treated in a variety of ways including recycling and digestion but with some 20,000 tonnes ending up in landfill.

Given that the majority of municipal waste arisings are delivered to the waste treatment plants in mixed form (i.e. all types of waste randomly mixed together) it is only at such a plant that there could be any application of AD technology. Leicestershire already boasts a new AD plant at one of their main treatment facilities and it would not be sensible or appropriate to consider attempting to intercept part of this waste stream for inclusion in another AD plant.

On the other hand, there is the vast amount of animal waste produced by the agricultural industry in Leicestershire. The waste produced by the cattle sector is estimated at over 1.6 million tonnes per annum, though only a small percentage of this material (perhaps half) will be possible to collect for re-use. The other livestock sectors within Leicestershire produce much smaller amounts of useable waste with most of the 60,000 tonnes of pig manure being produced in two very large pig units and the poultry sector producing a further 70,000 tonnes, though again much of this is not available for collection.

The vast majority of the available animal waste, approximately 90%, is therefore from the cattle sector and it is to this sector that we must turn for the prime feedstock for any AD plant, with the addition of pig manure in relatively small quantities where this is available. We must take great care when considering the inclusion of poultry litter as this material contains a very high percentage of inert bedding material and has a very high ammonia content which causes great problems with the AD process. Poultry litter can best be disposed of by a combustion process and much of this material in UK is presently burnt in large power stations.

The third waste disposal regime that must be considered in respect of this project is the disposal of the sewage sludge produced by sewage treatment works. The handling and disposal of this material is bound by very strict controls and legislative safety measures and its inclusion in an AD plant would have totally unacceptable implications on the possible and acceptable means of using the resulting digestate. No further consideration of this material will be made in this report.

The AD process itself, however, results in the production of three products that each have a waste disposal implication.

The biogas produced will be dealt with by its combustion in a boiler or CHP engine and hence has no further disposal implications.

The solid fibres can have a variety of uses, depending on the local markets that might exist in the locale of the chosen site. As this material forms only about 5% of the volume of the feedstock, it can easily be disposed of by being given to the farmers who have provided the slurry as a soil improver for their agricultural land. Another likely recipient of this material is the local authority parks and gardens departments. It is not considered likely that this material could be sold commercially as its production quantities are so low and the costs of having the material certified and tested prior to sale would cancel out any financial benefit.

The disposal of the liquid digestate is the crux of the AD system. This material constitutes around 95% of the volume of the feedstock but is an ideal liquid fertiliser. It has been assumed that this liquid will either be given to the farmers who provided the slurry or to a fertiliser contractor who can use this material as a much better alternative to spreading slurry.

It has been assumed that no charge will be made for the return of the digestate to the farmers as, without this, there would no incentive for the farmers to co-operate and bring their slurry to the plant.

8.2 Nitrate Vulnerable Zones

Any consideration of the disposal of animal residues to agricultural land must be made in relation to the designated Nitrate Vulnerable Zones that presently exist within the county and the likely spread of these zones in coming years.

Leaching of nitrates into rivers and ground water systems is causing serious pollution issues in many areas around the world. Drinking water quality is being reduced and at high levels can be a threat to human health. Nitrate ions can react with haemoglobin in the blood, with the result that the haemoglobin can no longer carry oxygen.

Nitrates that are carried to estuaries and bays by river systems can also cause rapid growth of aquatic plants (eutrophication). Microbial activity which occurs as the plants decay results in depletion of dissolved oxygen causing a hypoxic zone in which aquatic life is unsustainable.

Nitrate Vulnerable Zones (NVZs) have been developed in Europe as a response to these environmental issues in areas of high ground water nitrate concentrations. IN the UK almost all arable cropping areas have now been placed in NVZs. Farmers in NVZs are required to keep detailed records on fertiliser application to show that they do not apply manufactured fertilisers in excess of the crop needs. Restrictions have also been placed on manures with no applications to be made from August to November and the yearly total on arable land not to exceed 170kg/ha.

The Environment Agency have confirmed farmers' reports that the NVZs had not been successful in reducing nitrate levels to this point. Most farmers however agreed that NVZ requirements had been to their benefit by focusing attention on how efficient they were being with their own fertiliser applications.

Applied fertiliser therefore needs to be stable until rainfall and to be in a form that can be applied evenly and accurately. Ammonium nitrate is least likely to volatilise after application, however there are problems with availability (for purchase) and accuracy of application. Being a dry product it needs to be applied with a disk spinner or air boom or applied by air. While spreading technology is a lot more accurate now than it has been in the past it is still not as accurate as liquid application and cannot be varied on as small a scale as liquids.

There area a number of liquid nitrogen formulations the most common of which is urea ammonium or UAN. Half of the nitrogen in UAN is in ammonium form so it not as susceptible to volatilisation as plain urea but is slightly more susceptible than ammonium nitrate.

Compliance costs are also causing a change in the predominant fertiliser type in the UK, where there is a current move away from liquids back into solid fertilisers. In recent years there have been a number of liquid fertiliser spills in the UK that have resulted in severe and highly publicised environmental pollution. Responding to these spills the government has put in place costly storage and handling requirements for liquid fertilisers and is threatening even tighter legislation if any more incidents are recorded.

A total of 55% of England was designated as a Nitrate Vulnerable Zone (NVZ) in October 2002 and this includes large areas of Leicestershire. Farmers located in the NVZs have been required to apply Action Programme measures to reduce nitrate leaching since 19 December 2002.

The Nitrate Directive requires the identification of nitrate polluted waters using the following specific criteria:

- Surface freshwaters which contain or could contain, if preventative action is not taken, nitrate concentrations greater than 50mg/l.
- Groundwaters which contain or could contain, if preventative action is not taken, nitrate concentrations greater then 50mg/l.
- Natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or may become so in the near future if protective action is not taken.

Monitoring data collected by the Environment Agency from a network of monitoring points and boreholes is assessed against the above criteria for the identification of nitrate polluted waters.

The Nitrates Directive also requires all known areas of land draining into nitrate polluted waters to be identified for the digestion as Nitrate Vulnerable Zones (NVZs). Therefore, if an area of land drains into one or more of the above categories of polluted water, it will be located within a NVZ. Farmers located within these NVZs are required to adhere to an action Programme of measures to reduce the amount of nitrate lost from their land to the polluted waters. The effect of this legislation is to make it ever more difficult for farmers in NVZs to control the application of chemical fertilisers and manure. The crucial advantages of applying the digestate from an AD plant are:

- It can be injected easily into the soil

- Nitrogen release to atmosphere is minimised

- The strict controls on the application of manure are removed because the digestate does not lie on the surface of the soil where it can easily cause run-off.

- The uptake of the nutrients in the digestate is faster and more complete than with manure spreading giving better results than manure and lower total nitrogen escape.

9.0 Environmental and Legislative Framework

9.1 Environmental Impact Assessment

The location of the proposed AD plant will be dictated by the need to provide access for supply of agricultural slurry and transport of digestate from the site, while being within an economically viable distance to provide the proposed district heating scheme.

The overall site area for a Parish Scale plant will be approximately 100m by 100m, with the buildings on site totalling a 5000m² footprint.

Environmental Impact Assessment (EIA) is a process that identifies the environmental effects (both negative and positive) of development proposals. It aims to prevent, reduce and offset any adverse impacts and the intention is that the environmental effects can be considered from a very early stage.

There is a statutory requirement for EIA to be applied to significant development projects. EIA is, however, only required for such a project if it is judged likely to have significant environmental effects and a definition of the scope required of this EIA can be requested. A formal determination may be requested from the local planning departments. In this sub-section we identify the main environmental effects in order to facilitate this process and to identify the legislative frameworks that are likely to be of relevance.

Alternatives
Alternatives to the present proposal for a combined heat and power plant fuelled by biogas derived from animal slurry and food waste include:

1. No new development, continued reliance on exiting slurry infrastructure and continued reliance on imported fossil fuels.

2. Combined heat and power plant running on biomass derived fuels

3. Other renewable options including wind generation.

There is no alternative for slurry treatment, other than land application.

While continued reliance on fossil fuels for space heating is possible, it is contrary to the renewable energy strategy of both the council and central government.

Biomass and wind power are alternatives but for both there are well-recognised limits to the siting options. Biomass has been successfully used elsewhere, but the availability of the cattle slurry and the environmental problems associated with existing practices suggest that if commercially feasible the present proposal should be the Best Practicable Environmental Option.

Land Use Issues
The land required for the plant itself is relatively modest. The plant, vessels and associated buildings can be designed to be sympathetic to the rural character of the area. Typically the digesters themselves will be cylindrical vessels similar to the slurry stores already present on many farms. The plant is a small/medium scale industrial development and can be sited in rural area or near settlements. There may be issues with transport and odour but these will be dealt with as described below.

The effect on dairy and beef farms which will provide feedstock is that the odours associated with land spreading of untreated material will be greatly reduced.

The ease of application of the digestate when compared to untreated slurry will mean that constraints on its use can be eased.

The proposed plant will lead to a direct improvement in surface water quality due to reduction in the application of untreated slurry to land. The proposed plan will also improve the long term sustainability of dairy and beef cattle farming and provide a low-cost disposal route for other food wastes.

Geology Hydrogeology, Topography and Soils
The geology and hydrogeology of any proposed sites will be examined as part of the site selection process. At present no problems are foreseen as most of the plant and pipework will be above ground and the foundation requirements are not onerous.

Human Beings and Material Assets
The effect on local communities and material assets will be almost all positive. The plant offers the opportunity for some local employment and will protect jobs in the farming community and the food industries. Improved capacity for local generation of heat and power will contribute to self sustainability of the county, and reduced dependence on fossil fuels will increase the material assets within the county boundaries.

The reduced pollution from application of untreated slurry to land will improve the natural environment throughout the farmed areas of the county.

Noise and Vibration
The plant will operate 24 hours, however deliveries to and uplifts from the plant will be restricted to normal day-time operation. Plant noise will be low and attention to the noise levels of pumps, and material handling equipment will ensure that the noise levels from the operational plant are within environmental noise limits for the selected site.

Air Quality and Climate
The effect on air quality will be mainly positive. Increasingly the impact of agricultural activities on air quality is being recognised. The storage and application of livestock manure and slurry is the dominant source of ammonia emissions. Complaints about agricultural odours arise mainly form slurry or manure spreading. The collection and treatment of agricultural slurries will reduce these ammonia emissions. Untreated slurry in storage for long periods will also produce methane. The controlled use of slurry will reduce these fugitive methane

emissions.

The displacement of fossil fuels for space heating will reduce emissions of greenhouse gases and conserve non-renewable resources.

Use of CHP also contributes to reduced greenhouse gas emissions as the technology is a more efficient use of primary energy.

There will be additional fossil fuels consumption from the use of lorries to transport the slurry and digestate, but a number of studies have shown the net energy balance is positive and the net effect is a substantial reduction in greenhouse gas emission.

There will also be a potential odour emission from the plant, from air displaced from the storage tanks under filling operations and from periodic de-sludging of the reactor vessels. Odour migration strategies will be considered at the design phase and mitigation proposals advanced.

Transportation
The proposed plant will process slurry requiring 18 – 30 tanker movements per week. The planning support document will need a traffic impact assessment and access and egress to the site will be designed to meet the requirement of the local Roads Department.

Landscape and Visual Intrusion
The small scale of the plant and its likely location back from the road means that it can be landscaped into the environment and if necessary screened using tree planting. Plant layout and design will consider visual impacts.

An option to be considered at the design stage is incorporation of a visitor centre at the plant which could be a focus for environment and renewable energy in Leicestershire.

Ecology
No ecological impacts have been identified.

Water Quality
There is no requirement for effluent discharge from the process parts of the plant. All material will be in a form suitable for the fertiliser product. Any out of specification material will be recycled through the plant.

The net effect on water quality will be positive with a reduction ion coliforms entering surface water from application of untreated slurry to land.

Cultural Heritage
It is anticipated that none of the proposed sites will have an impact on cultural heritage.

9.2 Mitigation of Environmental Impacts

The overall environmental impact of the plant is positive. The plant will reduce existing levels of land and water pollution from agriculture and the permitted effluent discharge from food producers. This in turn will enhance the overall sustainability of agriculture, effectively increasing the usability of the existing animal slurry resource and lead to improvement in accuracy of nutrient dosing through the use of liquid fertiliser rather than untreated slurry. This will lead to a reduction in the use of inorganic fertilisers.

Collecting slurry and producing liquid fertilisers will also reduce direct atmospheric discharges of ammonia and reduce the odour caused by spreading untreated slurries.

The reduction in ammonia and odour will result in improved local air quality, which will enhance the quality of life of those who live in proximity of farms and enhance the air quality for tourism.

The production of biogas for CHP will contribute to action under the climate change agenda by reducing the dependence on fossil fuels.

The sale of energy and heat will help isolate the county from fluctuations in fossil fuel prices and contribute to the positioning of leicestershire as a leader in the field of the implementation of renewable energy.

The removal of limits on slurry and manure storage and the provision of a sustainable disposal route for food waste will contribute to the commercial viability of dairy farming and the creamery.
The plant will provide several jobs which will support the local economy.

Against these positive environmental benefits, two potential negative impacts have been identified:

Odour
During normal operation odours may be generated by off-loading from delivery vehicles and ventilation of storage facilities. Odours may also be generated during periodic de-sludging operations. Identification of sensitive receptors to odour will be a consideration during the site specification process. Where other considerations such as traffic impacts; the need to be linked to the electricity grid; and the viability of the district heating scheme; suggest that the site should be located near sensitive receptors for odour, then technical mitigation measures will be considered.

Traffic Impacts
Prior to planning the developers should undertake a formal site selection exercise which takes account of the identified environmental and traffic impacts.

It is anticipated that in view of the potential bad neighbour categorisation of the site, the local Planning Department will expect to see a robust approach to site selection.

9.3 Specific Legislation

AD technology for the treatment of organic wastes meets the strategic objectives of both existing and impending legislation, all emanating from the European Union.

9.3.1. EU Landfill Directive

The EU Landfill Directive sets out exacting targets for the reduction of the disposal of biodegradable waste to landfill. The agreed target dates for the UK are 2010, 2013 and finally 2020, by which time the maximum amount of biowaste permitted to be landfilled is 35% of that landfilled in 1995, since when there has been an annual increase in waste production in the UK of about 3%. An AD plant will help towards the diversion of biodegradable waste to landfill through beneficial recycling of organic waste.

9.3.2. Animal By-Products Regulations

The Animal By-Products Regulations, which became law in 2003, set out the standards by which animal by-products, including domestic kitchen waste, may be recycled as a biofertiliser through the natural biological processes of aerobic composting and anaerobic digestion. The objective of these regulations is to protect animal and human health by preventing the spreading of pathogenic organisms such as salmonella and e.coli.

Anaerobic digestion coupled with pasteurisation (70ºC for one hour) and operated to high professional standards, has been proven to eradicate these organisms.

9.3.3. EU Waste Prevention and Recycling Thematic Strategy

The EU Waste Prevention and Recycling Thematic Strategy aims to promote more sustainable waste management and recycling where the potential exists for additional environmental benefits are to be made. i.e. the recycling of nutrients.

9.3.4. Energy White Paper

The Energy White Paper sets out specific targets for the reduction of green house gas emissions with a 60% decrease by 2050 and significant progress by 2020.Anaerobic digestion can contribute to this two fold; the capture of greenhouse gases that would otherwise be released into the atmosphere, and the offsetting of carbon emissions (CO_2.equivalent) through the use of biogas and bio-fertilisers where fossil fuels would otherwise be used.

9.3.5 Planning & Permits

The development of an anaerobic digester imported waste and animal by products require the following permits.

- Planning Permission – Local/County Council
- Waste Management License – Environment Agency
- Animal By Product Regulation Approval – State Veterinary Service

9.4 Waste Strategy for England 2007

Whilst all of the foregoing legislative frameworks are well matched to the proposed AD plant developments, there exists a published government strategy for Waste in England into which the proposal should also fit.
The strategy aims to reduce waste production at source but also includes a fundamental aim to recover the energy from waste resources as being preferable to disposal. Under this strategy, local authorities are required to work with their communities to plan and invest in new reprocessing facilities, which definition would include AD technology.

A key objective of the strategy is to get the most benefit from recovery of energy form wastes and this would encourage the development of AD plants. This objective will involve the need for incentivisation and that is intended to include, among other things, enhanced capital allowances for AD plants.

The strategy also specifically identifies AD technology as being an exemplar of best practice in the disposal of food and green wastes financed through Renewables Obligations and PFI eligibility. It is anticipated that the application of energy from municipal waste will rise from 10% to 25% by 2020.

10.0 Procurement Options

There are a number of possibilities for the procurement of an AD plant in Leicestershire. In previous decades it would likely have been the local authority who would have made the decision to build such a plant and who would have taken on board all of the risks associated with such a development. This is not, however, a viable model at the time of writing.

Another obvious model for the procurement of the plant is for a private developer to decide to build one for entirely financial reasons and to operate the plant as a profit-making enterprise. This approach is, however, fraught with problems associated with the difficulties of any “bad neighbour development” perceptions and also the need to engage with a wide cross-section of the local community who will be needed to co-operate in the operation of the plant.

10.0.1 Traditional Procurement

This is the normal method of procuring any substantial construction project. The parties involved include:

- The developer
- The design team
- Other professional advisers (legal, accountancy, etc.)
- The tendering contractors
- The selected construction company

In this method of procurement the developer may a be an individual, a company or a corporation. The developer may be any kind of company, including a Community Energy Company. The legal and financial standing of the developer will need to be such as to satisfy the requirements of the funding bodies involved.

Once the developer has decided exactly what he wishes to procure, and where he wishes to build it, he would appoint a design team to prepare outlines of the project and obtain Planning Permission from the local authority.

In the case of a building project, the design team leader would normally be an architect, but in the case of an engineering project, the team leader would normally be a consulting engineer.

Also in these early stages, the developer will typically ask a lawyer to make preliminary negotiations regarding the purchase of the land for the development and ask an accountant to help prepare a Business Plan for the proposed development.

Once the project receives Planning Permission and purchase of land has been concluded, the design team can proceed to draw up detailed plans for the development and obtain Building Warrant for the proposals.

It is possible for the design team to draw up fully detailed plans and specifications for the development then use these to seek tenders from construction companies. It is also possible for the design team to draw up performance Specifications for the development and use these to seek tenders from “Design and Build” companies.

In the case of a process plant such as that in question, it would be normal to define the parameters of the process and require a specialist “Design and Build” contractor to develop the specific process equipment, whilst the rest of the development is handled in the traditional manner.

Once the development is complete, it would be handed over to the developer, whose staff will be instructed in its Operation and Maintenance. The plant will be operated by the developer and the profits retained for re-investment or distribution to shareholders.

10.0.2 Design, Finance, Build and Operate

This method of procurement was used to construct the Holsworthy Biogas plant, though it has subsequently become an independent company that owns and operates the plant.

In this method, a specialist constructor is appointed at the outset to provide a “turnkey” service whereby the constructor assumes a very large proportion of the operational and financial risk associated with the plant. This can include not only the design and construction of the plant, but also the raising of finance and responsibility for the operation of the completed development.

The direct corollary of this assumption of risk, is the retention of profits by the contractor. In this case, the developer simply pays for the products of the plant, at a price that includes the constructor’s costs and profits, and obtains no other benefits form the development.

10.0.3 Community Ownership.

The following section examines some specific examples of community ownership models that currently exist in the UK with a view to establishing those elements, which could usefully contribute to a practical solution in Leicestershire. Each case study is set out in terms of a brief introduction, information on how the organisation works and ownership issues, information on funding, a synopsis of the targets and aims of the project and information on how the projects are implemented.

Community investment in, and ownership of renewable energy projects such as biomass schemes are common in Germany, Austria, Sweden and Denmark. However, with a few exceptions, such community ownership has not flourished in the UK. It has succeeded in countries where the planning regimes and government assistance has been more supportive of community ownership.

10.1 Existing Exemplars

Within the UK there are a few examples of where Community Trusts have been established to generate and distribute income form energy or heat sales which would be relevant in Leicestershire. While it is useful to review these and examine how they have been established and run it may be more appropriate to take the best elements of these schemes and develop a new model for the Biomass option in the county.

What all the schemes have in common is that they have involved not only local people but have been the focus for partnership activity which has enhanced their knowledge base for project development, harnessed wide stakeholder support and has allowed access to a wide range of funding support.

Funding is the key issue in developing a successful project and details of how to finance a Community owned renewable energy project are available from a range of sources including the Renewable Energy Investment Club. However within the present context it is likely that a bespoke model will be required and funding would be applied for within the context of that model.

10.1.1 **Lanarkshire Biomass Project**

The project began in 2000 as an element of the Councils and Local Enterprise Companies Vacant and Derelict Land, Greening Strategy. Initially it was considered that vacant and derelict land could be used for growing of energy crops that could be used to fuel biomass boilers. And while that remains a possibility, investigation into biomass has shown that this is more likely to be a longer-term solution and that in the more immediate term waste wood or wood form forest residues will be the likely fuel.

Local Organisations Ownership:
Lanarkshire Biomass is a public sector partnership comprising: North and South Lanarkshire Councils; Scottish Enterprise Lanarkshire; Scottish Natural Heritage; Forward Scotland and the Central Scotland Forest Trust. It has established a project fund and employs a project manager. However in the longer term a not-for-profit company, Lanarkshire Biomass, will be established that enters into long-term heat supply contracts with a cluster of users of heat, which at this stage are nearly

all Council owned buildings. The sale of heat will provide a secure revenue stream. This will enable the company to procure wood fuel boiler systems and install and operate them at the users sites.

Lanarkshire Biomass has established a steering group that meets bi-monthly and employs a project manager to carry out the project development to a pre-agreed plan. The Project has also developed a partnership with two manufacturers who are carrying out the detailed technical feasibility studies for the Project.

Funding:
To date all the funding for the Project has come from the public sector. The capital cost of the boiler systems and costs of the fuel supply chain will be partly met by the income form the sale of heat. And partly from grant aid via Scottish Executive, DTI and lottery grant schemes designed to support such projects. Lanarkshire Biomass has already secured £175,000 to meet development costs. Capital costs are subject to development of the business plan, but estimated at £1.85million, with an expected 50% from Grant Aid.

Targets and Aims

- the development of clean energy technologies
- the creation of jobs in renewable energy
- recycling of waste wood and forest residues as a fuel, and
- tackle Climate Change, by the replacement of fossil fuel with renewable energy heating systems.

Implementation:
To achieve the aims of the project, a commercial ‘not for profit’ bioenergy company (Lanarkshire Biomass) will be created to sell heat to a cluster of customers. Heat will be generated at sites like schools and visitor centres from wood fuel boiler systems that are owned, installed and operated by Lanarkshire Biomass. Wood fuel will be supplied to these boiler systems from a central supply depot, initially in the form of wood chips from waste stream. These new heating systems will each replace existing fossil fuel heating systems which are largely in need of replacement.

Through contact with a range of Departments, detailed technical appraisal of potential users has already been undertaken, including schools, hospitals, housing schemes and visitor centres.

The total installed capacity of heating will be 5 megawatts – which is roughly equivalent to the heat demanded by 5000 homes. This directly replaces 5 megawatts of fossil fuels heating provision. 3200 tonnes of carbon emissions will be avoided per annum. 5000 tonnes of wood fuel will be required per annum. The estimated capital costs are £1.85million with a gross revenue of £289,000 per annum and a net profit of £129,000 (excluding depreciation and return on capital).

A wood fuel depot will be established in a location that is central to the cluster of users to enable a wood fuel supply chain to be set up. Fuel will be chipped and dried and delivered as required to the users and deposited in on-cite storage hoppers that automatically feed the wood fuel boilers.

10.1.2 **Baywind Renewable Energy Co-operative**

This project was the first in the UK where a co-operative owned its own wind turbines. The six turbines, near Ulvertson and Millom in Cumbria, were built by a developer and then sold one by one to the community through a series of share offers. Members of the co-operative receive profits form the sale of electricity from the turbines.

Local Organisation and Ownership:
The Co-operative was founded by seven individuals from the local area who now form the Board of Directors. They bring a range of skills and experience, including engineering, accountancy and marketing. Baywind now has a membership of 1300 all of whom are share holders of the co-operative. Only 43% live in Cumbria. The Project is supported by a full time paid administrator who is also a director.

Funding:
Baywind has raised £2 million through share offers to its members. The minimum share holding is £300 and the maximum (by law) is £20,000. Voting rights are distributed equally amongst members, regardless of the number of shares held. A stake in the company is therefore within the reach of many people, but no single individual or organisation can have a controlling interest. Shareholders receive 20% tax refund on their investment under the Government's Enterprise Investment Scheme.

Targets and Aims:

- Generate renewable energy and enable the community to participate in its generation;
- Create economic benefits for the community from profits gained from the sale of electricity from the turbines
- Increase the uptake of renewable energy and community-formation of new co-operatives;
- Raise the profile of community renewable energy developments and help facilitate further projects of this kind.

Implementation:
The concept of the project was based on a successful Swedish co-operative called Vindkompaniet that built Sweden's first co-operatively owned wind cluster in 1990. They set up the Wind Company (TWC) in 1994, introducing the concept of community-owned wind initiatives to the UK. TWC helped the community to establish the Baywind co-operative. The company carried the financial risk of building the first farm and provided its enterprise in assisting Baywind to find shareholders.

Word of the scheme was spread through a large mailshot in the local area, adverts in the national press and extensive local media coverage. Although the share offer gave preference to locals, the size of the investment required meant that it was necessary to go beyond the immediate region to find investors. However the first share offer was so successful that it raised funds sufficient to purchase two turbines rather than the one which had been planned. Subsequent share offers also exceeded expectations. Between September 1996 and

February 1999 over £1.9 million was raised in share capital. The Baywind Co-operative now have purchased their next six turbines and the electricity generated is sold to the National Grid through a 15 year Non-Fossil Fuel Obligation Contract.

As a voluntary condition of the planning permission Baywind formed an Energy Conservation Trust for the local community to which 0.5% of annual income is given. The Trust promotes energy conservation by providing energy efficient grants and energy-saving products to local organisations.

10.2 Current Developments

The success of the Baywind project continues at the time of writing, and has sparked a series of similar projects all over the UK, from Devon to Aberdeenshire. The key to this success has to be the keen involvement of the public as well as the private and public sector partners.

This model of Community Energy Company has much to recommend it and can be seen as being a healthy and growing business model that could be replicated in some form for the development of an AD plant in Leicestershire.

The Lanarkshire Biomass Project has not developed fully as intended as a result of various problems with the structure of the group operating the schemes. Whilst the first few installations were on local authority properties. There has been little take-up from other building owners and the projected targets do not appear to be likely to be met.

It would be wise to take this business model as being one that should be avoided and to focus on business models that involve of the stakeholders in the developing body from the outset.

10.3 The Community Energy Company

The Community Energy Company (CEC) model as used by Baywind would probably not be entirely suitable for a project as proposed for Leicestershire. Whilst the basic concept of involving the community as shareholders in a potentially profitable business remains valid and worthy of inclusion, there will be much less clarity about who will benefit to what extent in this case.

The Baywind project has the happy simplicity of spending a capital sum and then receiving income from the sale of the electricity, which income is then used to support further development, and provide a return on shareholding.

With an AD plant there are far more complexities in the business model:

- Who provides the animal slurry in what quantities?
- Who provides the food waste?
- Who receives the digestate and in what quantities?
- Who receives the fibres?
- What price is the heat sold at and to whom?
- What price is the electricity sold at and to whom?
- Who operates the plant?

Only if the electricity is sold back to the grid, does an AD plant have the simplicity enjoyed by Baywind.

Consequently, there will have to be more stakeholders and of different types in any CEC set up to operate an AD plant of this type. The stakeholder list will, in any event, have to include the local farmers who have the slurry and who can use the digestate. On any of the larger scales, the provider of the land; the user of the heat and power; the distributor of the digestate and possibly fibre; the supplier of the plant; the maintenance company and the operating company will all have to be stakeholders, as will be the local authority, licensing and monitoring agencies, power companies, etc.

11.0 Funding Sources

A project such as this may be eligible to receive funding form a wide range of sources. Grants from both UK and European sources are potentially available for the project.

The section below will describe the most realistic and obtainable sources of funding available to the biogas project and the perceived "fit" between the project and the funding objectives.

11.1 Leader +

The Leader + is the continuation of activities under the LEADER II programme. It is more comprehensive initiative aimed at encouraging and supporting high quality and ambitious integrated strategies for local rural development with a strong emphasis on co-operation and networking between rural areas.

The Leader + Initiative is available to rural areas of UK. All rural areas will have the opportunity to submit proposals for developing strategies for economic regeneration, consistent with a selection process based upon a transparent and rigorous competition.

The Leader + Programme could potentially meet up 50% of the cost for the biogas project.

11.2 Lottery Funded Programmes

A range of funding programmes is available from the Nationally Lottery Sources. These include the "Renewable Energy Programme", and the "Big Lottery Fund".

A drawback with the Lottery funded programmes is that they are oprganised into a series of "rounds" of funding, the timing of which may not suit any proposed development.

11.3 European Funding

There are many streams of funding available from EU, including programmes such as LIFE and ALTENER.

As with the UK lottery funding, these funds are only available in a series of funding rounds and the programmes change quite quickly such that any comments on which grant funds would be best suited to this project could change within 6 months.

It will be necessary to carry out a review of available funds at the time that the project is slated to proceed.

The cost of preparing and submitting an application for EU funding is considerable and the chances of success are generally reckoned to be about 1 in 3, therefore this route should only be followed for a substantial bid of several millions.

11.4 Nitrate Vulnerable Zones Grant Scheme

In Nitrate Vulnerable Zones grants are available to support farmers to set up the infrastructure needed for compliance with the requirements of a Nitrate Vulnerable Zone.

Slurry storage provision, replacement or improvement is eligible for grants under this scheme. Grants are available, at a rate of 40%, on eligible expenditure up to an investment ceiling of £85,000 for each agricultural business.

Whilst this funding may not be directly relevant to the construction of a biogas plant, it could assist the participating farmers in making provision of slurry storage and handling digestate returns.

11.5 Energy Savings Trust

The Energy Savings Trust can offer grant funding to a range of energy related projects, including the provision of community energy and community heating.

EST offer grants towards the cost of carrying out Feasibility Studies (Development Grants) and also towards the capital cost of installations (Capital Grants).

As with the NVZ grants, this funding may not be directly applicable to the biogas plant but could be used to assist in the development of the community energy infrastructure.

12.0 The Business Case

The fundamental requirements for a project such as this to be viable are as follows:

- TECHNOLOGY: The technology must be mature and reliable as any major failure of the process would have drastic consequences on cashflow and the potential to bankrupt the business.

- LEGISLATION: The legislative framework within which the plant operates must be seen to be stable and predictable, such that compliance can be assured in future years.

- MARKETS: The commercial market place within which the plant will obtain and dispose of its inputs and outputs must be seen to be stable or predictable.

- FINANCE: The cashflow and return on investment calculations must be sound.

12.1 Technology

The technology in question has been in widespread use throughout Europe and USA for more than 15 years. During that time, the plants have operated successfully with a wide range of feedstocks and have often successfully migrated from one feedstock to another as market conditions have changed. An example of this can be seen at the Ballytobin biogas plant in Ireland where the operators were forced to abandon digestion of pizza waste in the wake of the “mad cow disease” outbreak, but have successfully taken on the digestion of other food wastes whose sourcing can be certified.

12.2 Legislation

The legislative framework within which the project would be required to operate has been discussed in detail in Section 9 of this report. In summary, there are no legislative constraints that are likely to inhibit the development of the project, nor are any changes anticipated that would adversely affect its operation.

12.3 Markets

There are two aspects to the markets that will affect this plant. The first aspect concerns the input materials, which may include animal waste, food waste and fuel crops and a balance between these materials which can be expected to change from month to month and down through the years. Fortunately, the technology proposed is capable of dealing with a wide variety of feedstocks and this aspect of the market can be seen to be of less concern to the long-term viability of the plant.

The second aspect of the marketplace is the disposal of the plant outputs. Crucial among these is the sale of electricity, the value of which is mostly determined by government policy (ROCs) and the increasing scarcity and cost of fossil fuels. Whilst it is impossible to be certain that a mechanism such as ROCs will exist for the whole of the life of the plant, it is almost certain that government support for renewable energy will remain an important and high-profile aspect of policy for the foreseeable future. Indeed, a current white paper is suggesting that the value of ROCs could be doubled in the near future.

The sale of heat to a community network can be seen as a stable long-term solution benefiting the plant operators and the heat users alike.

The disposal of the liquid digestate could become a major problem for the plant if it cannot be disposed of back to the land, but given the pressures of NVZs and the need to control the use of manure as well as chemical fetilisers, this material should become ever more popular as a fertiliser and should be in ever greater demand as time passes.

The disposal of the fibrous residue is a matter of much smaller importance to the viability of the plant and it is to be expected that it will be able to be "given away" with zero cost implication for the foreseeable future.

12.4 Finance

The financial viability of the project is the single most crucial aspect of tis potential survival. Obtaining the necessary loan funding and grants is a relatively simple matter so long as the overall financial viability can be seen to be good.

In the longer term, the viability of the plant will depend on the income streams upon which the plant can depend. These sources of income are detailed in the appendices and summarised in Sections 6 and 7.

For the long term health of the plant to remain good, the following cash streams will need to be monitored:

- Sale of electricty to grid \ users
- Sale of ROCs
- Sale of heat to users
- Gate fees for incoming wastes

It is to be expected that every on of these income streams will increase in value as time passes and that the financial balances presented in the appendices can be expected to improve.

It will be an essential of any grant or loan application that a sound financial case can be presented for the proposed plant. This requirement, more than any other, will drive the project towards the larger scale of operation as per Section 7.1.

13.0 A Hypothetical Case for a Centre for Excellence

Although AD technology is commonplace in many parts of Europe, it is much less so in UK, other than as a means of reducing sewage sludge volumes in treatment works.

There are, however, a small number of operational plants, on the scale being considered here, presently extant in the UK, including one in Leicestershire operated by Biffa and processing domestic refuse.

To help establish the technology in the marketplace as a "waste to energy" process with valuable add-on benefits for the agricultural sector, it is considered necessary to establish a pilot scheme in Leicestershire. We have identified a number of possible sites for such a plant, including Brooksby College near Melton.

The college are keen to participate in the project and it would have the following positive benefits:

- Establishment of an operational plant in Leicestershire.
- Use of the plant as a demonstration scheme to encourage wider uptake of the technology
- Use of the plant as an educational resource for the college and also for other schools / colleges / universities
- The college have a suitable site available for the plant that would have minimal planning restrictions
- The college can utilise the electricity on-site
- The college can utilise the heat on-site.
- The college can use some of its available land to grow fuel crops to investigate how much benefit can be gained form this approach
- The college can use some of the digestate on its own farm land

To facilitate the creation of this facility, we have held discussions with various parties to ascertain the extent of their willingness to be part of the development. The parties who have expressed a desire to be involved are as follows:

Leicestershire Council:	As a facilitating partner without financial involvement.
Brooksby College:	As the project promoter and owner of the land upon which is to be built. Also as consumer of the heat and power generated by the plant.

RWA Agriculture:	A Leicestershire based company with a high level of interest in the construction and operation of biogas plants who would be keen to build and operate the plant.
RAC Contractors:	A Leicestershire based company specialising in fertiliser application for farm land who have already identified the potential advantages of the use of the liquid digestate and who would be keen to take all of the available digestate.

This group of prime stakeholders would be sufficient to permit the creation of a Community Energy Company, with additional participation form whatever parties might wish to be involved and who could bring added value tot he project.

Once the plant is constructed, and contracts in place with a suitable number of local farmers, the plant can be operated as a profitable business but will also be designed to permit regular visitation for educational and promotional purposes.

In the future, it would be possible to envisage further spin-off projects being developed by the agricultural community themselves, perhaps through the creation of co-operatives in conjunction with other initiatives that would be able to make use of the heat and power generated by the plant, e.g. heated greenhouses, grain drying, etc.

In the event that more encouragement is required, we have also identified a site with similar positive factors as that at Brooksby College. This site is at Twycross Zoo, which presently has a significant annual cost for disposal of animal manure, as well as substantial demands for heat and power. We have spoken to the operators of the zoo and they have expressed an interest in being involved. Such a site would also be ideal for presenting the educational and promotional aspects of the technology.

Should further sites be sought, we have noted a number of facilities such as leisure pools that are located on the outskirts of towns where it may be possible to site and adjacent biogas plant and pipe the heat \ power into the facility.

The locations of the identified sites and the locations of adjacent dairy herds, etc., are shown on the following maps.

14.0 Conclusions

➔The technology that drives anaerobic digestion is well known and widely used throughout much of Europe.

➔The financial viability of such scheme has been investigated at a variety of scales and using a variety feedstocks including animal slurry, food waste and energy crops.

➔It is apparent that the economies of scale within the process technology drive the decision-making process towards larger scale plants and that farm-sized plants are unlikely to be viable. This is bourne out by the European market for these plants where parish-scale and municipal plants are the norm.

➔Leicestershire has a substantial waste resource from its animal husbandry and could easily support a dozen AD plants of parish scale.

➔A number of sites have been identified across the County suitable for a

parish scale AD plant.

➔We have identified a number of interested parties within the county who are already involved in the agricultural sector who would be able to form the basis of a Community Energy Company to procure and operate the “centre for Exellence”.

➔The financial, legislative and environmental landscapes are all favourable for the deployment of this technology and the procurement of the project should proceed now.

➔The first step is to carry out a detailed assessment of a particular site and the local community to permit the creation of a detailed model with the formation of the CEC as the procurement body.