BIOGAS REGIONS

An Introduction to Biogas and Anaerobic Digestion

A guide for England and Wales

BIOGAS REGIONS

Introduction

Biogas

Biogas is the name given to the mixture of gases that are produced when readily bio-degradable waste is digested by bacteria in the absence of air. The process is very similar to that which happens in the stomach of an animal (including humans). The mixture varies but the objective of a biogas plant is to maximise the methane content as this is the primary "fuel" gas. The other main component of biogas is carbon dioxide. The process to produce biogas is known as anaerobic digestion; anaerobic digestion technology is engineered in order to create the right climatic conditions for the anaerobic bacteria to breakdown organic matter.

Anaerobic Digestion

Anaerobic Digestion (AD) technology is used around the world to make fertilisers from organic wastes and to produce useful energy at a variety of scales and levels of sophistication. There are, for instance, thousands of very small digesters in countries such as Nepal and India that produce gas for cooking - using as feedstock the manure from but a few cattle or buffalo. This "intermediate" technology option is not widely deployed in most of Europe because it requires warm temperatures all year round but their larger-scale equivalents are common-place on the farms of Germany and Austria in particular. Whilst AD based on agricultural and food waste products is only just starting to be developed at a reasonable scale in the UK, the utilisation of AD in sewage treatment has been long-established in this country.

The Biogas Regions Project

The European Commission's "Intelligent Energy for Europe" programme has provided funding for a trans-national project known as Biogas Regions. In brief, that project builds upon the experience and expertise found within partners from Styria, Austria and Baden Wurttemberg, Germany and uses it, as appropriate, in the regions covered by the seven promoting partners. Severn Wye Energy Agency (SWEA) is the one UK partner and its area of activity is defined for this project as being Wiltshire, Gloucestershire, Monmouthshire and Powys. The Welsh Assembly Government has provided match funding for activity in Wales as part of its commitment to a Centre of Excellence for Anaerobic Digestion based at the University of Glamorgan. SWEA works closely with the University when undertaking activity in Wales.

An Advisory Group has been established in the UK, drawing upon expertise from a wide range of organisations and individuals. That group has helped to steer activity in the SWEA region and, for instance, has considered and adopted a regional strategy.

The Biogas Regions project commenced in November 2007 and will end in October 2010. The other promoting regions are in France, Belgium, Poland, Spain, Italy and Slovenia.

SWEA

Severn Wye Energy Agency is a not-for-profit company and charity that seeks to promote sustainable energy and affordable warmth in the south west of England, and Wales. It has offices in Gloucestershire, Swindon and Mid Wales and employs over 40 staff with a wide range of skills, knowledge and experience.

With the support of:

Intelligent Energy Europe

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Short Description of Anaerobic Digestion

The Raw Materials (Feedstock)

The feedstock (sometimes also known as substrate) for an anaerobic digester can be a very wide range of bio-degradable materials but generally do not include materials high in lignin (woody products) as these are very slow to break down under anaerobic conditions. The feedstock can be grown especially for the digester (e.g. maize silage) or constitute a waste product of one sort or another. The waste products might be from livestock farming (mostly manures), the food processing industry, the municipal and commercial waste streams (e.g. food waste), abattoirs, grass from parkland or lawns or other sources. The ideal mix of feedstocks will contain carbohydrates, proteins and fat. Manure is often a useful base feedstock as it contains healthy anaerobic bacteria.

The Biochemical Process

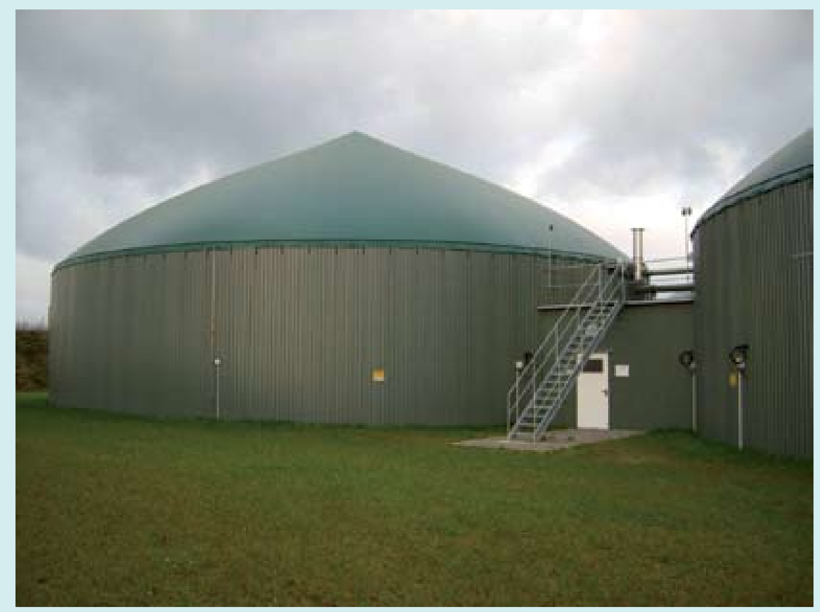
The breakdown of the chemical chains of the feedstock material is complex, involving four different processes. Hydrolysis is the first stage which breaks down the chemical bonds of fats, carbohydrates and proteins to form sugars, fatty acids and amino acids. Acidogenesis breaks down the products of hydrolysis, degrading them into carbon dioxide, hydrogen, alcohols and organic acids including acetate. Some of these products (e.g. acetate, hydrogen and carbon dioxide) can be directly used by the methanogenic bacteria in the fourth stage of anaerobic digestion (methanogenesis) to produce methane. Other products; some alcohols and organic acids, e.g. propionate (propanoate), butyrate (butanoate) and ethanol, need to be degraded into acetates by acetogenic or acetate- forming bacteria (acetogenesis) before they can be used as a substrate for the methane-forming bacteria.

If all the processes are operating in unison, they create their own natural buffer against the feeding of acidic feedstocks (through the production of calcium carbonate), then the pH will remain stable between pH 7.5 and 8 with a gas quality of between 55% and 65% methane.

The four processes within anaerobic digestion, hydrolysis, acidogenesis, acetogenesis and methanogenesis, separate as they are, can occur simultaneously within a single digester vessel. They are strongly dependent upon each other and when things are not working well they can cause mutual inhibition. For this reason, amongst a number of others, it is critical that the contents of a digester are agitated/mixed as they would stratify if left alone and the processes would slow. The early stages (hydrolysis) are the fastest and methanogenesis formation is the slowest.

The temperature of the digester is another key determinant of process and an issue that is carefully controlled. The digester can be designed to operate either within the mesophilic range (32-45 degrees C) or within the thermophilic range (50-60 degrees C).

Most commercial plants operate mesophilically as the process is more stable and therefore easier to control. Thermophilic processes produce gas more quickly and thus material can be retained in the digester for shorter periods, but there is a greater requirement for energy to run the plant and the sensitivity of the biochemical processes are a significant disadvantage. Whichever process is chosen, it is important to keep the temperature as even as possible.



It is absolutely critical to remember that anaerobic digestion is a process that relies upon living organisms that will react to the conditions around them and the food that they are given. The organisms are capable of reproducing very quickly but will also be killed or suppressed by toxins such as antibiotics and disinfectant (in significant quantities).

The Advantages of Anaerobic Digestion

Recycling Nutrients - Fertiliser Production
The anaerobic digestion process, unlike aerobic composting, locks in the nutrients and they are concentrated in the material that comes out of the digester - known as digestate. This material is an excellent product - directly displacing mineral N,P,K (nitrate, phosphate and potash) fertiliser. It is usually suitable for organic farming systems so long as it can be guaranteed to be free of Genetically Modified material (GM free).

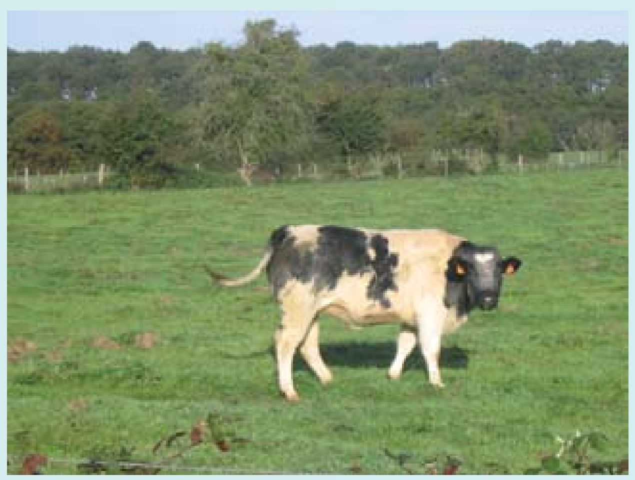
Mineral fertiliser is produced from fossil fuels so has a high carbon footprint and a monetary cost that reflects the fluctuating price of oil. AD digestate by comparison has a negative carbon footprint and has predictable production costs. The value of this fertiliser product sometimes appears to be underrated but, in most cases, offers very significant agricultural and environmental benefits.
It is not always necessary or desirable to separate the liquid and solid fraction of the digestate but where this is undertaken, the solid fraction becomes a potentially valuable soil-improver.

The Avoidance of Uncontrolled Greenhouse Gas Emissions
With the exception of crops especially grown for biogas production, other feedstocks would all otherwise decompose and depending upon their nature and the circumstances of their disposal, would release greenhouse gases. Biodegradable organic material that is land-filled will release methane - a very powerful greenhouse gas. Biodegradable material that is burnt releases pollutants including particulates and oxides of nitrogen and sulphur. Whilst landfill sites often have landfill gas recovery systems even the most efficient of these will be likely to release at least 10% of the methane produced through the anaerobic decomposition of the organic waste in the tip.

Cost-Effective Waste Management Option
This advantage is directly linked to the avoidance of greenhouse gas emissions in that it is this objective that has been the driving force for the European Union directive and UK law that has introduced legal and fiscal incentives to divert biodegradable waste away from landfill. Despite the costs involved in separate collections for biodegradable waste, local authorities simply cannot afford to continue with old practices. Food waste in particular has to be diverted for (in-vessel) composting or energy recovery. Industrial and commercial undertakings are similarly incentivised through financial penalties to seek routes of disposal that do not involve landfill.

AD offers an attractive option from a financial perspective because gate fees (the cost of handing over the waste) are usually more competitive than for the alternatives. The reasons for this lower gate fee lie in the major income streams that arise from energy production.

The energy generation relies upon the effective production of methane. The primary objective of the management of biodegradable waste is that it no longer produces methane upon decomposition. The two objectives are effectively identical - i.e. to extract as much methane as possible from the raw material.



A Flexible Source of Renewable Energy
Biogas is a fuel that can be used in a variety of ways to generate renewable energy. The process is deemed to be better than carbon neutral because it contains the methane gas from the natural degradation of organic materials to provide fossil fuel free renewable energy. This would otherwise be released into the atmosphere to become a greenhouse gas and is some twenty one times worse than carbon dioxide. Anaerobic digestion is a particularly fine example of a sustainable process because it represents a closed loop for the plant nutrients as well as the carbon dioxide. Another way of approaching the issue of the carbon dioxide emissions is to recognise the virtual inevitability of their short-term release - the biomass will decay to release carbon dioxide if simply left to rot.

A Vehicle Fuel
Biogas can be "upgraded" to filter out the vast majority of other gases - mostly carbon dioxide, and then sold as biomethane. Once compressed the gas is indistinguishable from the compressed natural gas (CNG) already sold at some filling stations. The emissions from this fuel are much cleaner than petrol or diesel.

If comparisons are made between biomethane and the more common vehicle biofuels of bioethanol and biodiesel, then biomethane performs very well indeed - easily outstripping its competitors in the number of miles per tonne of agricultural feedstock.

Biomethane as Mains Gas
Through a process similar to that required for vehicle fuel, biogas can be matched to mains gas which is also very largely methane. It can be injected into the gas main and sold as renewable fuel in much the same way as renewable electricity is sold from the electricity supply network. Once within the main it is indistinguishable from fossil gas so it is simply a matter of measuring and verifying the quantity injected and selling the same quantity as "renewable". This will be particularly important once fiscal incentives are introduced for renewable heat much as they currently exist for renewable electricity.

Renewable Heat and Electricity
The biogas can be used directly as the fuel for a gas engine or turbine to generate electricity and heat. Such a generator could be sited at the biogas plant, at a remote location with the gas moved by private, dedicated pipeline or at a remote site or sites using the route of conversion to bio-methane and injection into the public gas main. The gas can also be used in a gas boiler to provide heat only.

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South Shropshire Biodigester, Ludlow
Biocycle South Shropshire/BiogenGreenfinch Ltd.

The plant has been designed to process 5,000 tonnes per annum of household kitchen waste into biogas to produce renewable heat and electricity, and a biofertiliser that is returned to local agricultural land.

The initial feedstock was garden and kitchen waste but the garden waste contained a lot of contamination ranging from plastic bags right through to building materials and even car engines! The plant was operated on this feedstock for the first nine months. Subsequent to this collections were put in place in some regions to collect segregated food waste and the plant commenced operating using this feedstock only. Operating costs were much higher with the inclusion of garden waste but with lower biogas production.

The plant is closely monitored by Southampton University who will be putting together a final report sometime this year (2008) to document the inputs and outputs of the plant. This also includes the energy requirements of the plant.

"Since the introduction of a food waste only collection scheme for both households and commercial properties in Ludlow, the biodigester's performance has improved; with an increase in electricity production and an enhanced digestate". Craig Rogers – Plant Manager:

key data

Start of Operation	March 2006
Type of Corporation	Not for Profit

feedstock

Household and Commercial	
Source-segregated Kitchen Waste	5,000 tonnes pa

production data

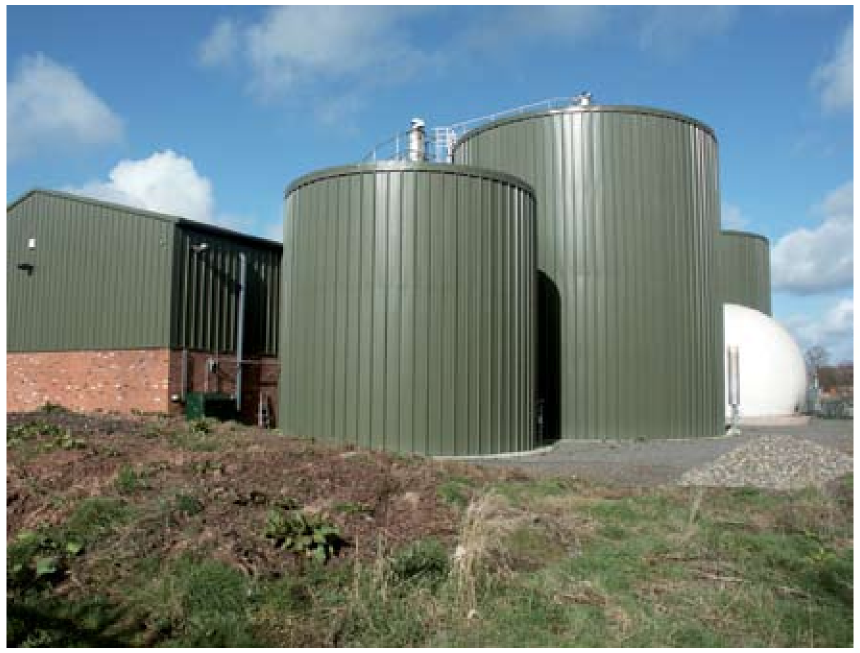
Available area for fertilizer spreading (sourced by agronomist who specialises in returning organic waste to land)	150 ha
Thermal power rating of the gas engine	315 kW
Generated thermal energy	2,600 MWh pa
Utilisation of heat (further utilisation under active investigation)	process heat only

Electrical rating of the gas engine	190 kW
Generated electricity per year	1,500 MWh
Electricity required by the plant (calculations to determine accurate figure are underway)	approx 10%

technical plant description

Digester	900 m³
Second digester	900 m³
Gas storage tank	150 m³
Residence time	25-30 days
Temperature of the anaerobic digestion (operational)	42 °C
Average expenditure of labour	24 hrs per day

For further Information, please visit
www.greenfinch.co.uk



Farmegy, Lowbrook Biogas plant
Dorset

The Lowbrook digester is now part of a farming enterprise that also includes 400 head dairy herd and 490 hectares of arable crops. The developer, Owen Yeatman, a third generation farmer, started to investigate anaerobic digestion and the opportunities that it offered for his business by travelling to Germany and visiting working plants. Convinced of the merits and the business case, he went ahead and built the biogas plant on his own farm, with the assistance of a grant from the Department for Food and Rural Affairs (Bio-Energy Capital Grant Scheme). The intention was to develop an exemplar project which would test the economics of AD from dedicated biomass under UK conditions.

The project is a very fine example of good practice in preparing for a planning application. The scheme and equipment was planned to sit well in the landscape and the support of community was gained through public meetings and presentations prior to the submission of the application. The development was approved within the 8 week statutory period – quite a rarity for AD plants. The feedstocks consist of 8,000 tonnes of cattle slurry, 1,000 tonnes of poultry litter and 3,000 tonnes of maize and grass silage. The process happens in a single digester of 2,800 cubic metres with a retention time of 60 days. The gas is used to generate electricity in an engine rated at 370 kW.

"Agriculture can help make a positive contribution towards solving the problem. Weather patterns have been changing in my farming lifetime. We can't continue to dump the amount of carbon in the atmosphere as we have previously and not expect to see changes. Like most farmers, I take the long term, multi-generational view of my business." Owen Yeatman

key data

Start of Operation	mid July 2008
Type of Corporation	Limited company
Amount of gas produced	1.357M m3 pa
Investment costs	€ 980,000

feedstock

Liquid manure (cattle)	8,000 tons pa
Grass/maize silage	3,000 tons pa
Poultry litter	1,000 tons pa

production data

Available area for fertilizer spreading	700 ha
Thermal power rating of the gas engine	424 kW
Generated thermal energy	3,230 MWh pa

Electrical rating of the gas engine	370 kW
Generated electricity	2,800 MWh pa
Electricity required by the plant	225 MWh pa
Electricity exported to the "grid"	2,564 MWh pa

technical plant description

Digester	2,880 m³
Residence time	62 days
Temperature of the anaerobic digestion (operational)	39-40°C
Average expenditure of labour	2.5 hours per day

For further Information, please visit
www.biogas-nord.com

Biogas plant Zeltweg
Thöni industrial firms limited liability company

This biogas plant was built for the military airfield of the federal armed forces in Zeltweg. The investments for the plant management was transferred to a contractor. Receiving a remuneration he delivers the heat for the army. The federal armed forces make the necessary feedstock (grass) available to the operator of the biogas plant. The digestate is used as a fertilizer on the green space of the military field. The green electricity, which is produced of the plant, is supplied in the local power grid. The biogas plant works with a two- stage process with one main digester and a second digester, which are made of concrete. The main digester has a concrete ceiling and the second one has a plastic membrane as a gasholder. Inside of the main digester are two paddle agitators and one submersible agitator. In the second digester are one paddle agitator and one submersible agitator. Maize, grass silage and whey is the feedstock of the biogas plant Zeltweg. The infeed of the solids is done over a separated hydraulic shear cotter floor, which transports the feedstock from the storage to a conveyor duct. It is possible to dose the feed rate exactly, because of the installed weighing machine. The whey is pumped through a slurry store, which has a special coating. Furthermore there is an external biofilter, which should avoid problems with the odour. The total residence time is 80 days. After a separation the liquid residue is transported to three lagoons, which have a total capacity of 2500 m³. The solids are used in the agriculture and is picked up daily.

key data

Start of Operation	2005
Type of corporation	Ltd. company
Amount of gas produced	2 150 000 m³ pa
Investment costs	€2 300 000

feedstock

Grass silage	8 000 tons pa
Maize	4 000 tons pa

production data

Available area for the output of the biogas fertilizer	250 ha
Thermal power rating of the gas engine	555 kW
Generated thermal energy	4 440 MWh pa
Utilisation of heat	federal armed forces
Electric power rating of the gas engine	500 kW
Generated electric energy	4,000 MWh pa
Power consumption (electricity) of the plant itself	400 MWh pa

technical plant description

Digester	1 500 m³
Second digester	1 500 m³
Gas storage tank	1 000 m³
Residence time	50 days
Temperature of the anaerobic digestion (operational)	40°C
Average expenditure of labour	6 per day

BiogenGreenfinch
Twinwoods Anaerobic Digestion (AD) Plant

Twinwoods AD plant, the first of its kind in the UK, was conceived in 2003 to solve the problem of dealing with the considerable amounts of pig slurry Bedfordia Farms were having to deal with each year, as well as finding an alternative and sustainable income for the business. The integrated AD approach was seen as an exemplary green solution to the significant food waste challenges that also exist in the UK. The slurry is pumped into the AD plant via an underground pipeline. The food waste upon arrival at the reception area at the plant goes through a packaging removal unit. The two feedstocks are then mixed to create a 'porridge' like consistent feedstock which is then passed through a pasteurisation unit where it is heated to 70 °C to meet strict regulatory requirements. The feedstock is then fed into the digesters on a 'little and often' basis every 4 hours where it remains for approximately 30 days before being pumped into the final storage vessels. The methane rich biogas generated from the process is collected in the dome roofs of the digester before being fed to a Combined Heat and Power Unit to produce renewable electricity. The BIOGEN Twinwoods plant has a combined generating capacity of 1.2MW – enough to power over 1000 homes. The majority of this is exported to the electricity grid. The heat generated is used to pasteurise the incoming feedstock as well as maintain the digesters at a constant temperature.

30,000 tonnes of liquid bio-fertiliser are produced which is spread to the arable land of Bedfordia Farms adjacent to the AD plant. The product has a two fold benefit. It is nutrient rich and has better crop capability and availability. This helps to avoid the nitrogen oxide emissions normally associated with the application of inorganic fertilisers. The bio-fertiliser also helps conserve increasingly scarce fossil fuel based fertiliser sources and cuts the energy use in the production and transporting of artificial fertilisers to the farm.

'We plan to create a network of our second generation plants in partnership with or as joint ventures with land owners, farmers and other interested parties who share our values and our commitment to protecting the environment whilst supporting rural communities'. Andrew Needham , Managing Director, BiogenGreenfinch

key data

Start of Operation	March 2006
Type of corporation	Limited Company

production data

Available area for fertilizer spreading	2000 ha
Thermal rating of gas engine	1.6 MW

feedstock

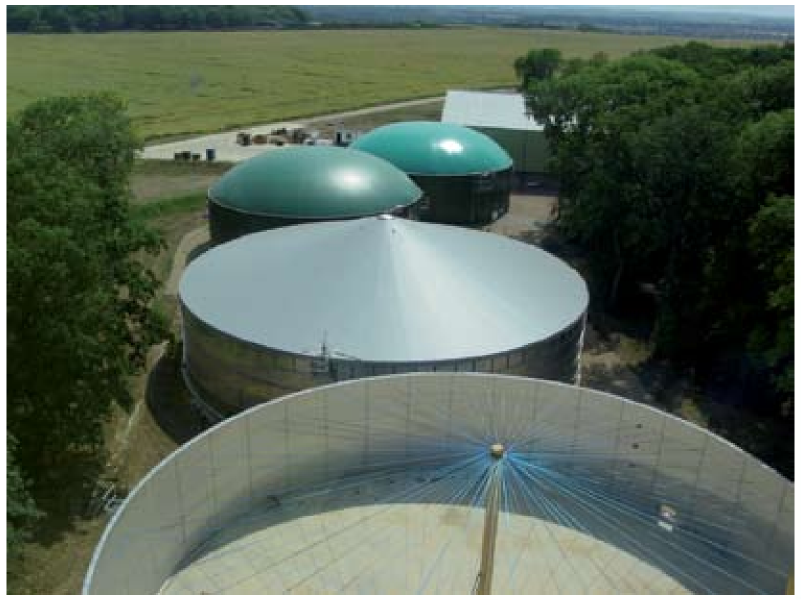
Liquid manure (pig)	12,000 tons pa
Food chain waste from local authorities, food processors & retailers	29,900 tons pa

Electrical rating of the gas engine	1.29 MW
Generated electric electricity	10,300 MWh pa
Electricity required by the plant	5%

technical plant description

Digester	not available
Second digester	not available
Gas storage tank	not available
Residence time	approx 30 days
Temperature of the anaerobic digestion (operational)	40 °C

For further Information, please visit
www.biogengreenfinch.co.uk



Short Description of Anaerobic Digestion Technology

Introduction
It is difficult to describe a "typical" AD plant because there is quite significant variation between plants depending upon the feedstocks in use, the resultant utilisation of the biogas, individual manufacturer's designs and the specifications of the client and his/her consultant. The vast majority of existing AD plants across Europe fall within the category known as "wet" systems but "dry" systems are emerging as a serious alternative. The following description is based very much upon the wet system with the main variations that arise in a dry plant briefly described later.

Feedstock Reception and Storage
This will vary tremendously from one feedstock to another. Liquid materials will usually be stored in tanks which may be underground. Energy crops will usually be stored in agricultural style clamps, silos or buildings whilst products such as food waste will be received and processed as soon as possible after delivery, within a building. Some feedstocks—those which might be associated with strong odours, will require reception facilities that control the smell by either pumping the materials directly from delivery vehicles into sealed tanks or by the use of buildings under negative pressure with odour control filters as part of the air handling system. Delivery vehicles may well be required to enter reception buildings and only unload their cargo behind closed doors. Some feedstocks will be delivered very infrequently e.g. energy crops that are harvested annually, and therefore require very large storage capacity whilst others are delivered daily e.g. food waste.

The Feeding System
The feedstock for most AD plants is introduced in relatively small quantities at regular intervals. Where there are mixed feedstocks these would usually be introduced into the digester in constant proportions via one or more inlet pipes. Water or recycled liquid from the digester may need to be added to the new feedstock but this should all happen in sealed conditions.

The digester/s
The digestion process will take place within a sealed tank or tanks which are usually constructed in steel but may be concrete, plastic or some other material. Depending upon the biological processes to be used, the contents of the digester are maintained at even temperatures and so require a means of heating. There is also a requirement to agitate the contents in order to reduce the tendency for layering and the formation of a crust. This is often undertaken through the introduction of paddles or other stirring devices but can also be achieved by gas circulation where gas is extracted from the top of the tank and bubbled up through the liquid contents to mix them. Some materials which are classed as Category 3 animal by-products (e.g. food waste) are required to go through a pasteurisation process which involves heating the material to 70 °C for 1 hour in order to kill harmful bacteria including salmonella, Escherichia coli and Enterococcaceae. This is undertaken in batches pre or post the digestion process and in a separate tank to the digester.

Digestate Store
A tank capable of storing at least 6 months output of digestate is required in order to ensure that digestate is able to be spread under appropriate (dry) conditions.

Gas Storage
Gas storage either takes place at the top of the digester tank under a flexible membrane or within a separate storage facility alongside the digester. The equipment required to flare off excess gas is also a practical and safety requirement although it is clearly hoped that this will be rarely needed. Biogas stored within these systems is not explosive.

Equipment for Utilising the Biogas
The equipment relating to the generation of electricity/heat or the cleaning, and pressurisation of the gas is a relatively minor part of the operation in terms of the size of the equipment or the space taken to house it. It is clearly of importance that any engines or motors associated with these processes are housed within a building that is well sound-proofed.

Dry Systems
Wet systems require that the material to be digested is of a soup-like consistency and therefore pumpable. Dry systems move the feedstock and digestate in a more solid state using high pressure pistons or vehicles with "loading buckets". This usually means that dry systems digest the feedstock in batches rather than a continuous process.

Criteria for a Successful Biogas Operation

Technical Excellence
It is clearly important to have a plant that is well designed and constructed and it is strongly recommended that advice is sought from knowledgeable and experienced people at an early stage.

Operational Excellence
Operating an AD plant requires knowledge, skill, dedication and experience. It completely relies upon the health of a series of living organisms for its success and it is not a simple matter of following an instruction manual. Whilst a biogas operation, which is largely automated and computer-controlled, might run without much human intervention for many hours, there will always need to be someone close at hand to monitor the situation and react to emergencies or sudden changes in plant health.

Environmental Controls and Compliance
It is clearly of critical importance that the plant is operated within the various strict legislative requirements that govern environmental protection and the health and safety of those working in or living/working close to the plant. A biogas plant will not cause pollution to air, land and water unless it is very poorly maintained and operated. There is a theoretical possibility of explosion and real possibility of fire but only if the plant is operated very poorly (and outside the law). Regulatory authorities will monitor an AD plant very closely in order to ensure compliance. The plant needs to sit comfortably in the landscape and this requires careful planning and design.

Excellent Relationships with Neighbours
The operator of any AD plant is very well advised to pay careful attention to its neighbours in order to ensure that relationships are good and that there are no justifiable complaints. This process should start very early in the development process, preferably a good time before any planning application is submitted. Particularly in the UK, people are unlikely to know much about biogas and will be fearful of the technology. Developers need to offer reassurance and good information and probably should offer to take neighbours to visit an operational AD plant. The plant needs to be operated so as to avoid noise or odour nuisance and preferably confer some advantage to the close community - such as cheap heat energy.

This document is produced by Severn Wye Energy Agency as part of the Biogas Regions project:

Promotion of biogas and its market development through local and regional partnerships

Additional funding was provided by:-

Other partners in the Biogas Regions project