Introduction

Anaerobic digestion is the decomposition of organic matter within an almost airless environment. This can take place in specially designed tanks or in landfill. Suitable feedstocks include farm wastes, sewage and the organic fraction of general municipal waste. Anaerobic Digestion produces methane, which can be burnt to produce heat and electricity, and digestate, which can be used as fertiliser and a soil improver.

Photo 1.
Holsworthy Biogas Pant

South West Resource

The South West, with its large rural sector and a growing population, has considerable potential for more biogas plants. With waste disposal being such a great problem, biogas production could provide many benefits to the region in addition to the production of energy. The greatest proportion of the region's renewable energy generation is from biogas with 71 MW coming from landfill gas and 11 MW from Sewage Gas (2007 Project Survey, Regen SW). There is also expertise in the region from projects such as the Holsworthy Biogas Plant.

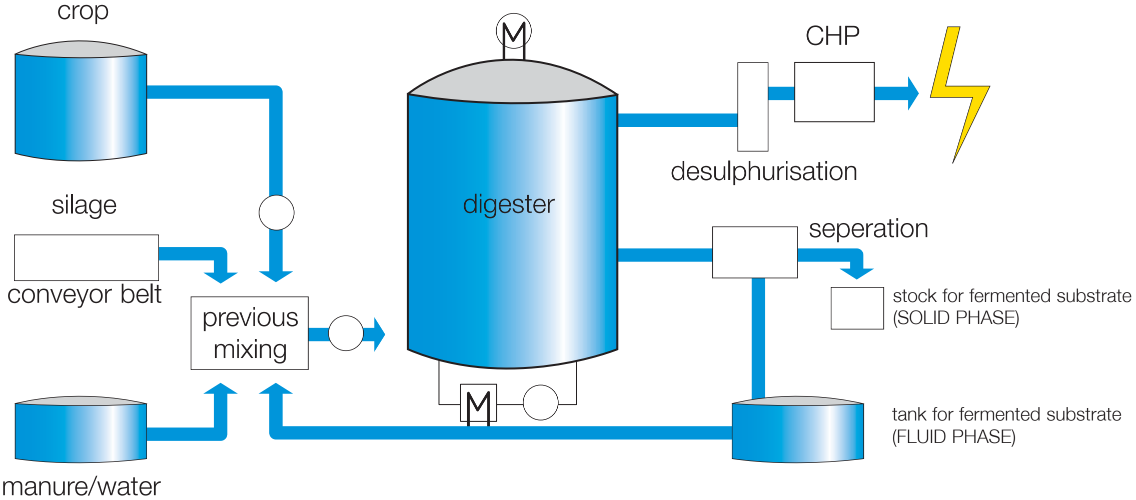
Photo 2.
Biofertiliser muck spreading

Technology

A slurry of organic matter and suitable bacteria held in an airtight container at a temperature of around 50°C will decompose to produce large quantities of biogas; a mix of 50-70% methane and carbon dioxide. This can be used on-site or burned in internal combustion engines to produce electricity (Figure 1). A similar process will also occur in the semi-anaerobic conditions found in many landfill sites.

The bacteria can either be those naturally existing in the slurry, as is the case with animal manure, or artificially introduced. The digestate left after digestion can be returned to the land and includes fertilising compounds rich in nitrogen. Such a system is sustainable in that an equivalent amount of carbon dioxide would have been produced if the waste had degraded naturally.

Figure 1.
Schematic of a biogas plant.



There are four stages to the process.

1. Pre-Processing. The feed stock is pre-treated to remove non-biodegradable materials, provide a uniform small particle size for efficient digestion and remove material that may decrease the quality of the digestate or damage downstream plant. For farm wastes this process will be simple and confined to grit removal and mixing with other organic wastes to ensue a near-optimum carbon: nitrogen ratio. For municipal wastes the process will be more complex and involve separation at source, or mechanical separation using manual sorting (to remove items such as batteries, building materials and other inorganics), rotating trammels or screens to remove large items, a hammermill to crush the waste and a hydropulper (a device that separates materials according to density).

2. Sterilisation. It may be important to sterilise the digestate if it contains animal products. In digesters operating at high temperatures this may occur naturally, with low temperature, mesophilic systems pre- or post-treatment at a temperature of 70°C will be needed.

3. Digestion. This can be single-stage, multi-stage or batch. Single stage digesters originated in the waste-water industry and consist of a single large reaction vessel. Multistage systems contain two or more vessels each concentrating on a different part of the digestion process and offer more control over the rate of the reaction. In batch processors the digester is filled once with fresh waste and allowed to go through all stages of digestion before more waste is introduced. Batch systems are technologically simple, often more robust and cheaper, however they need a greater floor area (as the reactor is typically only one fifth the height of an equivalent continuous system) and have a lower gas yield. Mesophilic systems are considered more reliable and require less heat to maintain the reaction, however they take longer to process the waste.

4. By-Product Use. Anaerobic digestion produces biogas and digestate.

Biogas. This has a similar calorific value to landfill gas at around 22 MJ/m^3, compared to 36 MJ/m^3 for natural gas, with the exact composition linked to the type of waste used. It may be necessary to remove some of the hydrogen sulphide and water vapour in the biogas to avoid corrosion within the boiler, or combined heat and power (CHP) engine. The gas can be burned within a boiler, used to run a CHP unit to provide electricity and heat or used as a transport fuel.

Digestate. The quality and therefore value of the digestate will depend on contamination, and nutrient content. Digestion concentrates these nutrients and produces a less odorous product. Single-farm digesters can usually make use of the digestate for soil improvement without any post-processing and it is relatively simple to separate the liquid and solid fractions, thereby producing a liquid fertiliser and a peat substitute for re-sale. Units processing municipal solid waste will usually require the use of post-processing technologies.

Suitable Wastes

Most organic wastes are suitable. Wet wastes, such as manure or catering waste are particularly suited because the high water content makes them unsuitable for combustion. Industries producing wet wastes include: food, beverage, starch, sugar, paper, slaughterhouse, chemical, pharmaceutical, dairies, cosmetics, fish processing, sewage and agriculture. It is perfectly feasible to use a mix of these wastes and create a community scale facility. Municipal solid wastes can also be used, although a high level of pre-processing may be required.

Scale

Traditionally most anaerobic digestion plants have been small-scale units, working at low temperatures and low solid content serving a single farm (with several thousand examples in Germany alone). There is now a move to much bigger units serving a community. This offers the potential for improved efficiency, economies of scale and the co-digestion of farm and municipal waste. **Table 1**, shows typical sizes and throughputs for wastes and **Table 2** shows the same but for sewage. For the treatment of municipal solid waste, a throughput in excess of 15,000 tonnes per annum is probably required [IWM Report on AD of MSW]

Table 1.

Throughput (tonnes per day)	Volume (m3)	Height (m)	Floor area (m2)
1 (farm-scale)	50-250	-	-
50	800-1,500	8-10	75-150
150	2,200-3,500	10-12	180-360
350	4,700	10	470
450	7,700	15	513

Table 2.

Community population	Daily sewage throughput (m^3/day)	Total digester volume (m^3)
7,000	1,000	180
21,000	3,000	380
30,000	4,500	800
60,000	9,000	1,350
200,000	30,000	3,400

Landfill

Water content in a landfill site is much lower than within slurry (which might be 95% water) and the waste is not kept artificially warm, so decomposition takes place much more slowly, typically over several decades. Methane escapes naturally from landfill and is a powerful greenhouse gas (twenty times that of carbon dioxide by mass). Being such a strong greenhouse gas gives an extra justification for capturing the gas and burning it to produce carbon dioxide to reduce the overall impact on the greenhouse effect.

The site is covered with a layer of clay to keep air out and to keep the gas from escaping. The landfill gas is extracted via a grid of interconnected pipes buried within the waste. Production rates of 3500 m3/hour of methane are possible from a large, well developed site, with around three GJ of methane being produced per ton of waste. Newer landfill sites will have some form of methane recovery, although it might only be flaring without energy recovery. Older sites may simply vent the methane to air.

Issues

Traffic. For plants taking waste from more than one farm, there will be an increase in local traffic, potentially causing a nuisance to neighbours. If the waste travels a large distance, the greenhouse gas emissions from the lorries will reduce some of the environmental benefit of the scheme.

Visual Impact. This will depend on the size of the digester and associated plant. Table 1 can be used to get an idea of the height of the digester.

Odour. This is a potential problem from untreated waste coming into the plant.

Noise. There will be noise from vehicles and potentially from a CHP unit.

Emissions. Provision needs to be made for dealing with the flaring of excess gas and measures introduced to reduce the possibility of liquid effluent polluting ground water.

Cost Payback. It is unlikely that a small-scale digester will be financially viable solely through electricity production. A reasonable payback is much more likely if the heat and the waste it produces can be used on the farm or nearby. There are examples of much larger facilities which have been financed on a commercial basis.

Maintenance

Maintenance will be dependent on the type and scale of the biogas system and the type of feedstock used. The operation and maintenance requirements of a proposed project should be detailed in the initial development stages to ensure costs and man-hours are included in the business case.

Planning Permission and Licences

Depending on the general scale of the system, planning permission will be focused on the visual impact of additional buildings and storage facilities, as well as issues such as odour. Larger systems may raise concerns regarding increased haulage of feedstock on local roads to the site. In general regulations and licences will be required with regard to which wastes are suitable for digestion, the way they must be handled and stored, and the production and use of any co-product. For example, a facility handling controlled wastes will require a licence under the Environmental Protection Act 1990.

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Connecting to the Grid |

Large biogas plants export electricity directly to the grid, small-scale installations can also be connected to the grid so that electricity that is not used on-site can be exported to the grid and so that the site can use grid electricity when needed. By buying an export meter (around £150) this surplus can be sold to an electricity supplier for around 2.5p per kWh. In addition, the owner of the plant would probably be able to receive Renewable Obligation Certificates (ROCs) for all the electricity generated, these can then be sold via a third party.

Finance |

Estimating the Potential of the Site

The amount of biogas produced will depend on the amount and type of waste, and the type of anaerobic digestion system installed. However, it may only be economic to process a fraction of the waste if there is not sufficient demand to use all of the energy generated (particularly the heat energy). Conversely, it might be worth considering involving others in the project in order to increase the size of the plant and generate economies of scale, or to ensure a year-round supply of waste.

For a farm of 600 cattle, of which approximately one-third of the waste could be collected, there would be a waste stream equivalent to 600/3 = 200 cattle. This should produce 333 m^3 of biogas per day, which could be burnt in an 83 kW CHP engine. Over a year, this could produce around 83 x (1/3) x 365 x 24 = 242,360 kWh of electricity and 484,720 kWh of heat, although the actual output is likely to be slightly less as the plant will not operate 100% of the time due to maintenance requirements. This electricity could be used on-site or exported, however the heat would have to be used on site, or nearby.

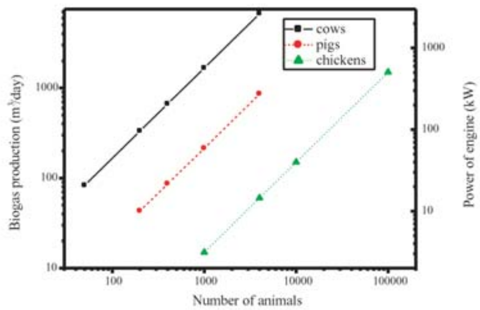

Figure 2. Relationship between type and number of animals and expected biogas production and power of CHP engine

Costs and Grants |

Costs for biogas plants are dependent on scale and system type. For example, a basic farm scheme may cost under £100,000 where as commercial scale systems will start from several million pounds. Important factors to take into account when costing a plant and formulating a business plan include additional expenditure, such as operational costs and required licenses, as well as potential income from gate fees for feedstock where relevant. Biogas plants do not generally fall under the same grant schemes as other renewable energy technologies. In some cases feasibility studies for smaller projects have been funded through community renewable energy funds, however, projects generally have difficulty in obtaining grant funding for capital costs. Funding streams accessed by previous biogas projects include European funding, Regional Development Agencies and rural economic development companies.

More Information |

- The Renewable Energy Association (www.r-e-a.net) has contacts for member companies working within the biogas sector.
- The International Energy Agency has a group dedicated to bioenergy and a UK-based expert to help answer your questions: see www.aboutbioenergy.info/technologies.html
- For information on connecting to and exporting to the grid see: www.quietrevolution.co.uk/downloads
- Companion Guide to PPS 22: The technical annexes. Available at www.odpm.gov.uk/planning

REW Renewable Energy World (www.earthscan.co.uk/news/article/mps/UAN/307/v/3/sp/3 32145698682330931486)