ANEROBIC DIGESTION and BIOGAS

Anaerobic digestion is the natural biological process which stabilises organic waste in the absence of air and transforms it into bio fertiliser and biogas. It is a 4-stage process: hydrolysis, acidification, acetogenesis and methanogenesis.

In the first phase anaerobic bacteria use enzymes to decompose high molecular organic substances such as proteins, carbohydrates, cellulose and fats into low molecular compounds. During the second phase acid forming bacteria continue the decomposition process into organic acids, carbon dioxide, hydrogen sulphide and ammonia. Acid bacteria form acetate, carbon dioxide and hydrogen during the acetogenesis phase. The methanogenesis phase involves methane forming bacteria producing methane, carbon dioxide and alkaline water.

The process of anaerobic digestion takes place in the intestines of humans and animals and in a landfill site, the latter in an uncontrolled manner. Anaerobic digestion has been widely used in Germany, Sweden, Austria and Denmark and the technology is well proven and established.

1. Biogas

The valuable component of Biogas is methane (CH_4) which typically makes up 60%, with the balance being carbon dioxide (CO_2) and small percentages of other gases. The proportion of methane depends on the feedstock and the efficiency of the process, with the range for methane content being 40% to 70%. Biogas is saturated and contains H_2S, and the simplest use is in a boiler to produce hot water or steam. The most common use is where the biogas fuels an internal combustion gas engine in a Combined Heat and Power (CHP) unit to produce electricity and heat. In Sweden the compressed gas is used as a vehicle fuel and there are a number of biogas filling stations for cars and buses. The gas can also be upgraded and used in gas supply networks. The use of biogas in a solid oxide fuel cells is being researched

1.1 Make up of Biogas

Component	Symbol	Percentage content of gas
Methane	CH_4	40-70
Carbon dioxide	CO_2	30-60
Hydrogen	H_2	1.0
Nitrogen	N_2	0.5
Carbon monoxide	CO	0.1
Oxygen	O_2	0.1
Hydrogen sulphide	H_2S	0.1

2. Production of Biogas

2.1 Feed Stocks

A wide range of materials can be used in a biogas plant. Energy crops can be grown specifically as a feedstock or by products and waste materials used. The most important differentiation for waste materials is those that include animal by-product (ABP) that require pasteurisation, and those that do not. Mesophilic and thermophilic bacteria responsible for the process are only able to work and multiply if their substrates are sufficiently dilute (they cannot exist on solids) making slurry an ideal substrate for the process.

2.2 Types of Feedstock

Source separated bio waste
Mechanically-separated municipal waste (ABP).
Food processing and abattoir waste (ABP).
Commercial catering waste (ABP).
Sewage sludge.
Animal slurry.
Vegetable and pack house waste.
Energy crops – maize/grass silage, whole crop wheat, whole grain maize.
Mixtures of the above.

2.3 Process Mechanics

Substrate from different feed stocks is mixed in a fermentation tank or biogas digester; a warmed, sealed airless container (the digester) which creates the ideal conditions for the bacteria to ferment the organic material in oxygen-free conditions. The digestion tank needs to be warmed and mixed thoroughly to create the ideal conditions for the bacteria to convert organic matter into biogas. Fermentation tanks allow production and collection of methane from the anaerobic process.

Gas is dried and vented into a gas engine connected to a generator to produce electricity. Heat can be taken off the engine to give combined heat and power. The slurry by-product is virtually odourless and is a uniform high value fertiliser. Heat produced is recycled to warm the substrate in the digesters.

2.4 Yields of different Feed Stocks

Production of electricity per tonne of raw material feedstock

Maize silage	402 kWh/t
Vegetable wastes	122 kWh/t
Grass silage	256 kWh/t
Slurry/manure	47 kWh/t

Typical gas production level and residue production (per tonne raw material)

Maize silage	= 200m3 gas (500kg liquid output)
Corn Cob Mix	= 500m3 gas (350kg liquid output)
Whole crop rye	= 600m3 gas (300kg liquid output)
Slurry	= 20m3 gas (978kg liquid output)

2.5 Different types of Anaerobic Digestion

There are two types of anaerobic digestion:-

Mesophilic Digestion: The digester is heated to 30 - 35^{o}C and the feedstock remains in the digester typically for 15-30 days. Mesophilic digestion tends to be more robust and tolerant than the thermophilic process but gas production is less, larger digestion tanks are required and sanitisation, if required, is a separate process stage.

Thermophilic Digestion: The digester is heated to 55°C and the residence time is typically 12-14 days. Thermophilic digestion systems offer higher methane production, faster throughput, better pathogen and virus 'kill', but require more expensive technology, greater energy input and a higher degree of operation and monitoring. During this process 30-60% of the digestible solids are converted into biogas.

Mesophilic digestion is the most common approach since it is more reliable and plant management is easier.

3. Advantages of Anaerobic Digestion and Production of Biogas

Processing organic waste anaerobically to create Biogas is a sustainable, renewable waste to energy solution. The process offers numerous advantages over conventional technologies and if waste materials are used in the process, can reduce greenhouse gas emissions in 4 ways:-

1. Preventing the uncontrolled emissions of CH_4 (22 times more powerful than CO_2) from landfill.

2. The Bio fertiliser produced can displace mineral fertilisers. Nutrients are conserved with more than 90% of nutrients entering anaerobic digesters conserved through the digestion process. By conserving nitrogen during digestion the N:P ratio of the treated manure is more favourable for plant growth[1].

3. Reducing the transport of waste.

4. Renewable electricity and heat can be produced, reducing greenhouse gas (GHG) emissions. Since anaerobic digestion operates in a closed system, substantial reductions in greenhouse gas emissions are achieved. Ammonia losses, while not of direct GHG concern, are also reduced.

3.1 Other Benefits of the Process

1. Odour levels are greatly reduced during manure processing, creating a relatively odour-free end product (closed vessel processing confines odorous compounds which are converted to other chemicals). The product of digestion has no more odour than compost.

2. Improvement in slurry characteristics such as: fluidity, crop compatibility, homogeneity, reduction of weed germs.

3. Anaerobic digestion greatly reduces pathogen levels. Pre- or post-digester technologies can ensure pathogen-free end products.

4. Production of electricity and heat provides valuable income.

[1] Reducing the demand for additional mineral nitrogen helps decrease the use of natural gas for production of new mineral nitrogen, as well as reduce greenhouse gas emissions associated with nitrogen fertilizer production.

5. Reduced land fill tax and climate change levy charges.

6. Income from Renewable Obligation Certificates (ROCs).[2]

7. Positive use of organic waste materials reduces land and water pollution.

4. Economics

The viability of an anaerobic digestion plant will depend on:-

- The availability of waste to give a feedstock of zero cost, and if a gate fee is charged for the waste received.
- Whether the electricity generated is displacing existing demand and the type of contract.
- The value at which the ROCs are traded.
- Whether value is derived from surplus heat and the biofertiliser produced.
- Scale and location of the AD plant

4.1 Arable crop feedstock

In Germany and Austria energy crops are grown specifically as a feedstock for Biogas production. In Germany legislation was introduced in 2001 whereby electric generated from renewable resources is directly subsidised by the government. The subsidy is guaranteed to generators for 15 years. The wholesale price for electricity is supported with top ups for use of energy crops and combined heat and power. The compensation is increased by 1 Cent/kWh if fuel cells, micro gas turbines or stirling engines are used for electricity production as opposed to an internal combustion engine. As a result of this support 72,000 ha of maize was grown for biogas production in Germany in 2005, and plant numbers in Germany increased in the period 2004 to 2005 by 690 plants with 2700 plants operational at the end of 2005.

Compensation paid for electricity [€-Cent/kWh]		
Electric Capacity	**Farm Substrates**	**Non-Farm Organic Wastes**
< 150 KW	14	11
< 500 kW	12	9
< 5 MW	8	8
> 5 MW	8	8

There is no direct subsidy for renewable electricity generated in the UK. Renewable electricity generators rely on the value of renewable obligation certificates to supplement the wholesale electricity price that they receive

5. Plant Costs

A rough guide to plant costs, and the potential income stream if waste materials and slurry are used as a feedstock, is summarised below. Dependent on

2 Under the Renewable Obligation Order the generation of electricity using renewable resources creates a Renewable Obligation Certificate for each unit of renewable energy generated.

construction specifications and site €1.5 – 2 M is the capital investment required for a green field site biogas plant using energy crops as a feedstock in Germany.

Plant Size	Capital Cost	Operating Surplus (per annum)
250 kw	£400 - £500k	£75 - £125k
250 kw ABP compliant	£800k - £1.2M	£150 - £300k
1 Mw	£1.2 - £1.6M	£400 - £600k
1 Mw ABP compliant	£2.5 – £3.0M	£800k - £1.2M

6. Biogas Plants in the UK

Anaerobic digestion plant development in the UK has been very slow with the most notable agricultural operation in Devon. Holsworthy Biogas Ltd was established in 1998 and is owned by Farmatic Biotech Energy, an entrepreneur, the local community and the supplying farmers. The plant has the capacity to process 146,000 tonnes per annum of cattle, pig and poultry manure plus organic food waste (20%). Generating 14.4 million kWh of electricity at approximately 6 p/kWh and eventually 15 million kWth of heat energy will be used for a district heating network.

Greenfinch have recently built 7 on-farm biogas plants built in Southwest Scotland for the Scottish Executive for research into diffuse pollution from agriculture.

Bedfordia Farms have a biogas plant using pig slurry and food waste near Bedford.

A DEFRA supported initiative between Greenfinch and South Shropshire District Council has seen the construction of a Biowaste digester recycling 5000 tonnes per annum of source-segregated kitchen & garden waste into bio fertiliser and renewable electricity in Shropshire.

7. Opportunities

Opportunities for biogas investment in the UK are likely to be in a rural business that has access to slurry and waste material or by products such as pack house waste. With greater capital investment and the ability to use animal by products, gate fees for food waste can provide a useful income stream. It is very unlikely with the wholesale electricity price in the UK and the support for renewable electricity through ROCs mechanism that it will be economically viable to grow crops specifically as a feedstock. However, crop grown potentially as a feedstock could help underpin the variability in availability of waste materials. The crop could be harvested and used if insufficient supplies of waste were available or to make a buffer stock of material.

Utilising the heat energy generated through a district heating network would significantly improve the economic case, so there is potential scope for biogas facilities in the proximity of new housing and development areas, particularly if a recycling scheme could be put in place to utilise kitchen and green waste from the housing as a supplement to other feed stocks.

Information

www.biogas-nord.de
www.schmack-biogas.com
www.weda-gb.com
www.greenfinch.co.uk
www.farmatic.com
www.hese-umwelt.de

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