# BIOMETHANIZATION TRAINING INFO

**What is biogas from anaerobic digestion?**

**ANAEROBIC DIGESTION - - BIOMETHANISATION - a natural process**

Anaerobic digestion – biomethanisation (AD) is indigenous to natural anaerobic ecosystems and represents the microbiological conversion of organic matter to methane in the absence of oxygen. The process is also known as the biogas process and has been widely utilised by modern society for stabilising primary and secondary sludge in wastewater treatment plants. AD is commonly used for the treatment of animal manure, organic waste from urban areas and food industries (co-digestion), more often associated with energy recovery and recycling of the digested substrate (digestate) as fertiliser to the agricultural sector.

Anaerobic digestion (AD) is a natural process during which bacteria break down the carbon in organic material. This process produces a mixture of methane and carbon dioxide, a mixture called biogas. The process occurs only in the absence of oxygen, hence the term “anaerobic” (literally meaning “without air”). Anaerobic digestion occurs naturally in the sediments at the bottom of lakes and ponds, in bogs and in the intestines of ruminant animals such as cows.

This ability of bacteria to produce methane from organic material has been harnessed in specially constructed anaerobic digestion plants. At the core of these

A plants is the digester tank -an airtight tank in which digestion takes place. The digester is fed with organic matter and produces biogas. The digested substrate is called digestate. The digestate consists principally of nutrient rich liquid and undigested fibres. The digestate can be passed through a separator, which separates a fibre fraction from the liquid. The liquid fraction is a fertiliser containing the valuable nutrient nitrogen and some of the phosphorus and potassium, in a form that is more available for the crops than in undigested slurry. The fibre-fraction, reach in phosphorus, can be composted to produce a high quality soil conditioner, with similar properties to peat in horticultural products. The biogas can be used


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to produce heat in a gas boiler, or electricity and heat using an engine and a generator or it can be purified and used as vehicle fuel. Latest research shows possibilities to use biogas for fuel-cells and hydrogen production.

Thus, an anaerobic digestion plant has three main products:

- Biogas, for energy production
- Liquid fertiliser
- Fibre for compost

Anaerobic digestion plants can be constructed to operate at any scale. On-farm digestion plants are generally small and treat only slurry produced on the farm. Biogas is usually burned in a boiler to supplement farm and home heating requirements. Large-scale anaerobic digesters to which organic matter from a variety of sources is brought are called centralised biogas plants. Biogas from such plants is generally passed through a Combined Heat and Power plant (CHP). The electricity generated is fed to the national grid, while heat is used locally.

## BIOCHEMICAL BASICS

The anaerobic digestion process occurs in the following four steps:

1. ***Hydrolysis***: large polymers are broken down by enzymes.
2. ***Acidogenesis***: acidogenetic fermentations are most important, acetate is the main end product. Volatile fatty acids are also produced along with carbon dioxide and hydrogen.
3. ***Acetogenesis***: Breakdown of volatile acids to acetate and hydrogen.
4. ***Methanogenesis***: Acetate, hydrogen are converted to methane and carbon dioxide.


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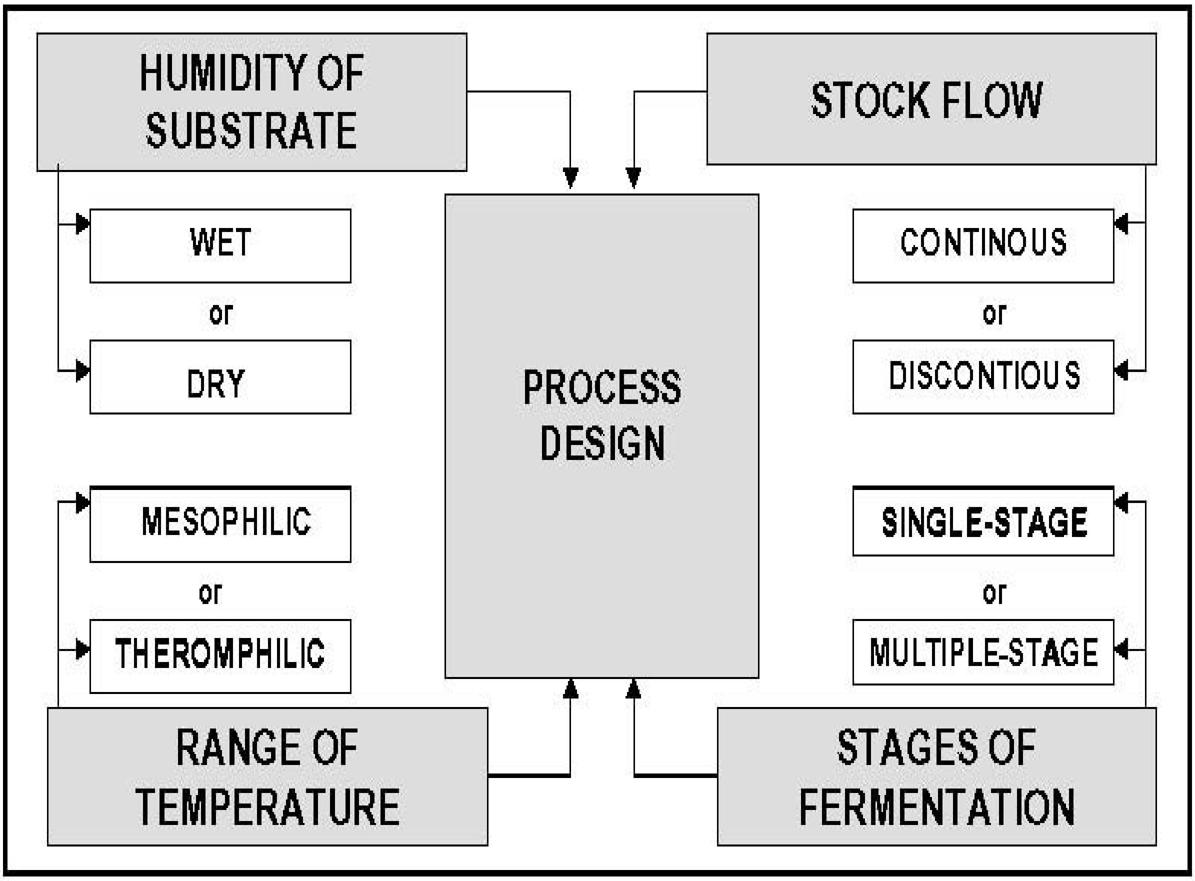
## PROCESS DESIGN AND TECHNIQUE

Figure 1: *The four principles of AD process design*




In the fermentation processes two different temperature ranges are distinguished:

- mesophilic temperature from 25 °C to 35 °
- thermophilic temperature from 49 °C to 60 °

The majority of the agricultural biogas plants are operated at mesophilic temperatures. Thermophilic temperatures are applied mainly in large-scale centralised biogas plants with co-digestion, where more stringent sanitation requirements are required [1].

The mode of feeding can be continuous or discontinuous. In discontinuous batch systems the fresh substrate is fed together with an inoculation of digested material into a reaction vessel. During one or two days the material is aerated in order to increase the temperature. During the following two or three weeks the substrate is anaerobically degraded, at first with an increasing daily gas production. After having reached a maximum after approximately 10 to 14 days, gas production decreases again to reach a plateau of about half the maximum production. To compensate for the unsteady gas formation three to four batch digesters are operated in parallel but filled at different times. Batch systems until recently are not very common for agricultural biogas plants [1].

Another form of the discontinuous process design is the storage systems. They combine digester tanks and retention tanks in one and the same tank. The combined fermentation and holding tank is slowly filled with fresh manure depending on the produced amount. The advantage of this system is the low costs. However problems may arise from high heat losses and unsteady gas formation rates [3].

Accumulation continuous flow (ACF)-systems are the most popular digester design in farm scale biogas sites. The fresh manure flows into the digester as it is produced. The digested manure is removed occasionally, when it is needed for fertilisation. When no fertilizer is needed, the full digester overflows into a holding tank, which is covered by a rubber membrane serving as a gas storage.

Another popular system is the continuous flow tank reactor. Here the raw waste is pumped regularly into the digester, displacing an equal volume of digested material. The volume in the digester remains constant. Most of the smaller systems are fed once or twice a day. The larger digesters are operated more continuously with feeding intervals of less than one hour. There are several types of digester designs and mixing systems as shown in figure 4.

***A biogas plant involves more than just a gas tight manure pit or a digestion vessel, it is usually built up of four elements :***

- The production unit, which includes the anaerobic digester,
- A holding tank and/or a sanitation unit and the manure removal system.
- The gas storage and gas upgrading system
- *The equipment for gas and manure utilization*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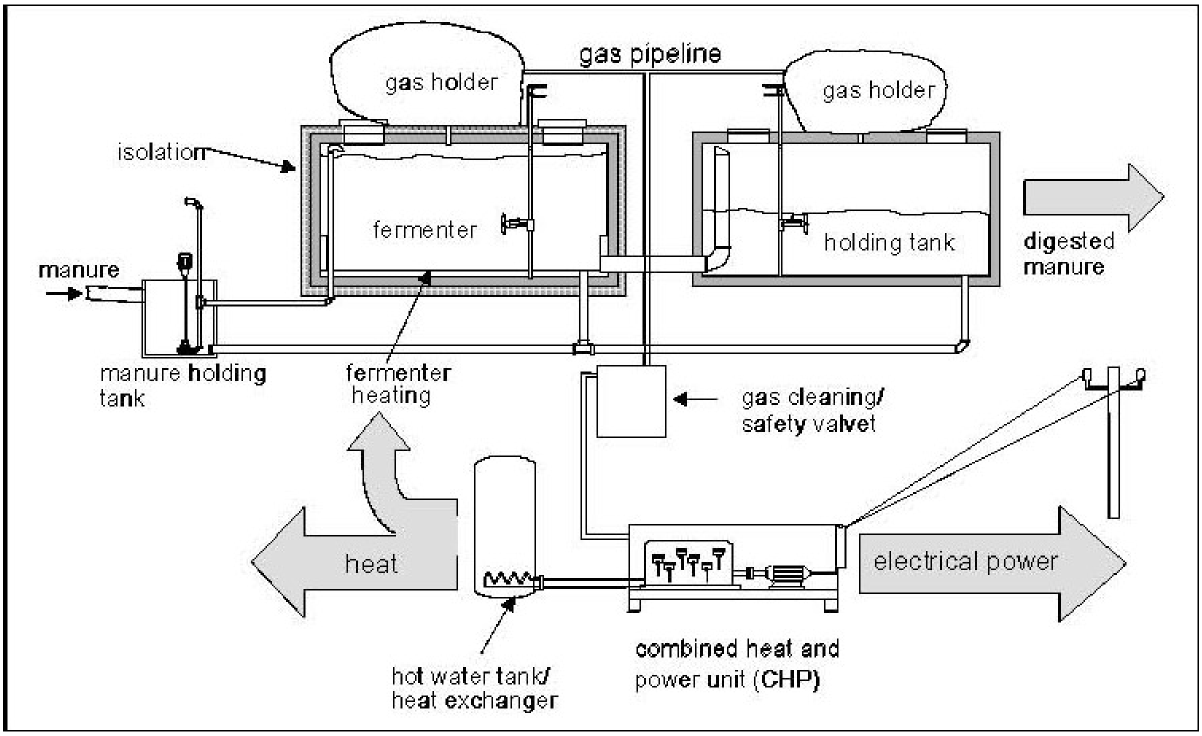


Figure 2: Biogas process flow

There are countless types of designs for each of the four elements. The digester can be designed horizontally or vertically. The horizontal design has the following advantages: efficient and energy-saving mixers can be used. In horizontal digesters the fresh substrate is not mixed with the digested substrate at the other end of the digester (plug-flow). In this way high gas yields are achieved. For technical and economical reasons horizontal digesters are only built up to a maximum volume of 200 $m^3$, for the Hungarian small unit case up to 200 $m^3$.

For Biogas plants with reactor volumes over 300 $m^3$ usually digesters with vertical design are used. They are usually built of concrete with a round cross-section for structural reasons. Compared to the vertical design, the vertical digesters have the advantage of a better ratio of surface to volume. Thus material requirements and thermal losses are reduced. A key disadvantage is the fact that plug flow cannot be achieved.

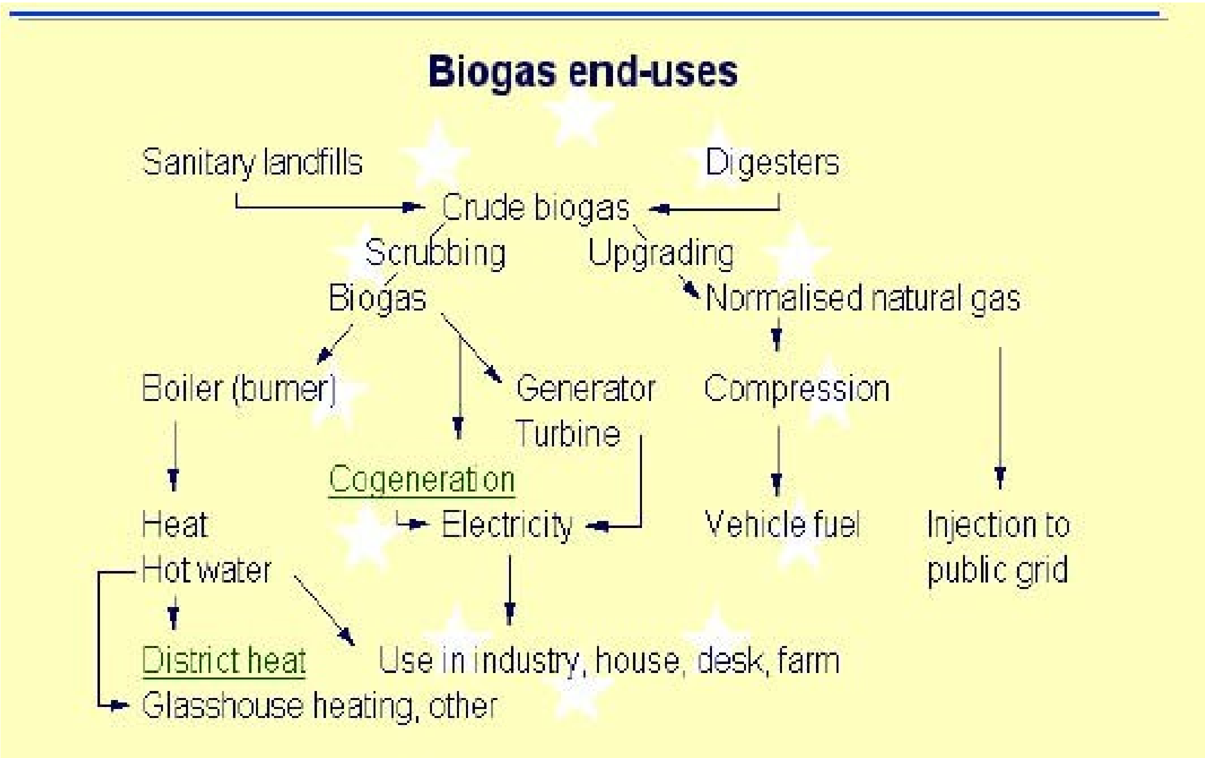


Figure 3: Biogas end-uses.

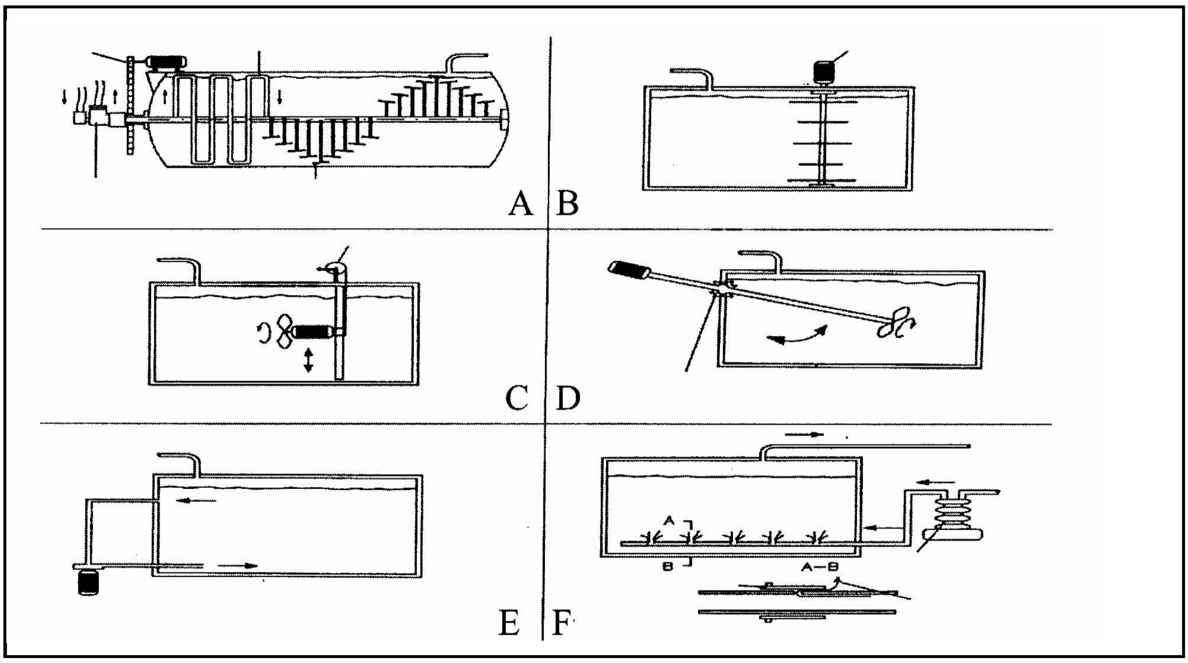


Figure 4: Different types of digesters and mixing systems.

A: Horizontal digester with horizontal paddle stirrer.

B: Vertical digester with vertical paddle stirrer.

C: Vertical digester with adjustable propeller stirrer.

D: Vertical digester with propeller mixer on a swivel arm.

E: Vertical digester with hydraulic mixing.

F: Vertical air lift digester.

The substrate in an agricultural biogas digester is usually mixed for the following reasons:

• Inoculation of the fresh substrate with digestate

• Distribution of heat to achieve an even temperature through out the digester

• Avoid or disrupt scum and sediment formation

• Release of biogas bubbles trapped in the substrate

If the substrate is not mechanically mixed it tends to separate, i.e. it forms a sediment and a solid scum. The scum is particularly difficult to remove after it has dried out through continuous gas production. The different types of stirrers are shown in figure 4.

In larger digesters usually two to three mixers are applied in different depths of the digester. In small size plants only one stirrer is installed for economical reasons. It is therefore important that it is adjustable for the mixing of a possible scum and sediment formation.

For all mixing purposes mentioned the speed of rotation is not important. Usually slowly rotating mixers are applied with rotations as low as 15-50 rpm. Again, not all types of stirrers are equally well adapted for all possible substrates. Hydraulic and pneumatic stirrers are restricted to dilute substrates such as pig manure with little potential for scum formation. A horizontal paddle stirrer on the other hand, is especially well designed for straw-rich cattle manure. However, it can also handle more dilute substrates. The most widely used stirrers are propeller mixers. They allow the most flexible application with respect to the substrate composition and the form and size of the digester. The only limit is the temperature for submerged motors. Above a digestion temperature of 40 °C there is not enough cooling.

Once the digester is working properly the quality of the produced biogas has to be improved. Usually sulphur removal is necessary to avoid corrosion, which can damage the CHP unit and lead to high sulphur dioxide emissions after combustion. In on-farm biogas sites the biological method to remove hydrogen sulphide from the gas is applied in many cases. This system uses the ability of sulphide oxidising autographic microorganisms like Thiobacillus oxidants to convert H2S to elementary sulphur and sulphate. For this microbiological oxidation air has to be added to the biogas. Usually the required air is added directly to the digester or in some cases also to the gas holding tank or to a special gas-cleaning unit. The amount of air needed for the process ranges between 2 % and 6 % of the biogas, depending on the H2S concentration. For large digesters (e.g. in centralized AD plants) external biological scrubber columns or chemical adsorber columns are often applied, however this might be an expensive solution for an Hungarian small farmer.

The most common utilisation of biogas is in combined heat and power engines (CHP) or, in the case that electricity injection into the grid is not possible, heat production by burning in a boiler. For smaller biogas plants CHP units with double fuel diesel engines are mainly used if the installed electrical capacity is less than 100 kWel. These engines need the injection of approximately 8-10 % of diesel fuel for ignition and are therefore able to handle a variation in quality of the used biogas. Applications with higher biogas yield are suitable to use gas-otto engines, which do not need the addition of liquid fuel and show a higher electric efficiency. In future fuel cells may be a commercial option and depending on local legislation the injection of biogas into the national gas grid are possible alternatives for the use of biogas (figure 5).

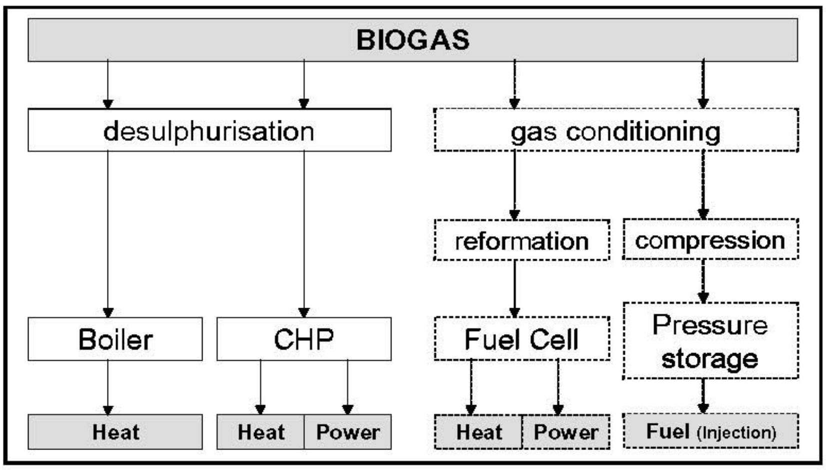


*Figure 5: Scheme of different possibilities to use biogas.*

# European legislation affecting the biogas sector

Anaerobic digestion (AD), together with composting, represents a sustainable, natural route of treatment & recycling of wastes of biological origin and a wide range of useful industrial organic by-products. The Hungarian legislation in technical terms also following these EU legislations.

Caused by a steadily increasing biowaste collection in Hungary (which is located in a sensitive water base in the Carpatian basin), treatment and recovery, numerous EC-regulations and guidelines have been issued in this area, or are currently under development. Most of these regulations profoundly influence the technological developments and practical applications of AD. The most important pieces of legislation are now presented.

### *1. COUNCIL DIRECTIVE 75/442/EEC OF 15 JULY 1975 ON WASTE*

Directive 75/442/EEC contains definition of wastes, together with guidelines for waste classification as well exclusion of specific wastes (e.g. radioactive materials, animal carcases, waste waters). Member States shall take the necessary measures to ensure that waste is disposed of without endangering human health and without harming the environment. In article 3 member states are requested to take appropriate steps to encourage the prevention, recycling and processing of waste, the extraction of raw materials and possibly of energy there from and any other process for the re-use of waste.

### *2. THE SEWAGE SLUDGE DIRECTIVE 1986/278/EEC*

The directive 1986/278/EEC "Protection of Environment and Soil at the Utilization of Sewage Sludge in Agriculture" defines limiting values for heavy metals, organic trace compounds and defines hygienic requirements for handling and application of sewage sludge on agricultural soils. In addition the Regulation on Organic Farming 2092/91/EWG defines heavy metal limiting values for compost derived from source separate collection of municipal biowaste.

### *3. THE WATER FRAMEWORK DIRECTIVE 2000/60/EC*

The water framework directive affects water industry, agriculture, development and construction industry and all businesses that have discharge consents, trade effluent licences or abstraction licences. The aim of the 72 pages Directive is to establish a framework for the protection of waters. As its name suggests, the Directive sets out a framework for action rather than imposing a set of rules.

## 4. COUNCIL DIRECTIVE 1999/31/EC ON THE LANDFILL OF WASTE

The EC directive on the landfill of waste defines the goals of organic waste reduction in landfills (based on the year 1975) as follows: Reduction to 75 % by the year 2006, reduction to 50 % by 2009 and to 35 % by the year 2016.

## 5. TOWARDS A THEMATIC STRATEGY FOR SOIL PROTECTION – COM(2002) 179 FINAL

The Commission will present a thematic strategy on soil protection in 2004. The strategy is

one of seven 'thematic strategies' foreseen under the EU's Environment Action Programme. It will consist of legislation on community information and monitoring system on soil, as well as a set of detailed recommendations for future measures and actions. The monitoring system will build on existing information systems and databases and ensure a harmonised way of establishing the prevailing soil conditions across Europe. By the end of 2004 a directive on compost and other biowaste will be prepared with the aim to control potential soil contamination and to encourage the use of certified compost.

## *6. DIRECTIVE 2001/77/EC ON THE PROMOTION OF ELECTRICITY PRODUCED FROM RENEWABLE ENERGY SOURCES IN THE INTERNAL ELECTRICITY MARKET*

The document states, that the exploitation of renewable energy sources is underused in the Community at the moment. For this reason the directive aims to promote an increase in the contribution of renewable energy sources to electricity production in the internal market for electricity and to create a basis for a future Community framework thereof. To ensure increased penetration of electricity produced from renewable resources, the member states are requested to set appropriate national indicative targets. The EC “White Paper” indicative target of 12 % by the year 2010 provides a useful guidance. Biogas is one of the possible renewable alternatives and its broader penetration, as an energy source should therefore well benefit from these efforts.

## 7. WORKING DOCUMENT BIOLOGICAL TREATMENT OF BIOWASTE

Currently the second draft version of the forthcoming regulation "Biological Treatment of Biowaste" is available. The current version has to be harmonised with the recently published Animal By-product Regulation (EC) No 1774/2002. Furthermore it has to be adopted to the EC "Thematic Strategy for Soil Protection" – COM (2002) 179 final. A revised third version of "Biological Treatment of Biowaste" has been announced for the year 2004.

The forthcoming regulation will contain:

- a list of allowable wastes for bio-treatment,
- directives for waste collection, handling and treatment,
- approval of treatment plants and allowable processing emissions,
- quality classes for bio-treatment residues and compost,
- control and analysis of end-products and
- *application standards for the end-products.*

In the current version, hygienisation of the bio-waste has to be guaranteed by a

- minimum temperature of 55 °C for at least 24 hours, at an average hydraulic dwell time in the reactor of at least 20 days.

If that is not guaranteed than a

- pre-treatment at 70 °C for 1 hour or a
- post-treatment of the solid digestate at 70 °C for 1 hour or
- *Composting of the solid digestate is required. Concerning quality standards, 3 categories of solid end product (compost) respectively stabilised waste have been defined. According to category 1 and 2 compost qualities, land application quantities will be regulated.*

## 8. ANIMAL BY-PRODUCTS REGULATION (EC) NO 1774/2002

The Regulation (EC) No 1774/2002 of the European Parliament and the Council from 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption (ABP, Animal By-Products Regulation) has to be applied in all Member States since May, 1st 2003.

Animal by-products (ABP) are defined as all animals or parts of animals not intended for human consumption. This includes dead on farm animals, animal manure and catering waste. Catering waste means all waste food including used cooking oils originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens.

Since inappropriate processing standards and the use of rendered products and catering waste are believed to be the main reason for major pandemic outbreaks of BSE (Bovine Spongiform Encephalopathy) and FMD (Foot and Mouth Disease), consequently rigorous measures had to be taken. The new regulation will require major changes in processing procedures by both waste producers and waste managers. In this Regulation 3 "risk – categories" are classified and new rules for the collection, treatment and disposal of animal by-products, including animal manure and catering waste (kitchen waste, restaurant waste etc.) are introduced.

### 8.1 Classification of animal by-products in 3 categories

Based on their potential risk to the public, to animals, or to the environment the Regulation (EC) No 1774/2002 (ABP regulation) classifies all animal by-products and their processed products and wastes into three categories and defines the corresponded treatment and utilisation possibilities.

Category 1 materials

Category 1 concentrates on animal by-products presenting the highest risk to the environment, animals or humans. This category contains, with others, the following materials:

- Animals or materials suspected or being infected by TSEs (Transmissible Spongiform Encephalopathies: BSE, MSE, FSE etc.)
- The SRM (specified risk materials) representing the material of (healthy) animals having the highest potential of containing the TSE pathogen such as the scull of 12 months old sheep and cattle and the intestines of cattle of all ages.
- Animals or parts of them with exceeding residues of environmental contaminants (e.g. dioxins, PCBs).
- Catering waste originating from international means of transport.
- Animal Waste collected in the wastewater stream of category 1 processing plants with a particle size > 6mm. Category 1 processing facilities have to apply a wastewater pre-treatment system removing all animal material with a particle size of more than 6 mm.

There are no proper treatment facilities in Hungary for Cat 1 waste.

Category 2 materials

This category includes the following materials:

- Animals, or parts of them, representing a risk of being contaminated or transmitting any animal diseases (e.g. animals which die on farm or are killed in the context of disease control measures).
- Animal by-products with exceeding values of veterinary drugs.
- Animal Waste collected in the wastewater stream of slaughtering facilities (category 2 processing plants), with a particle size > 6mm (fat scraper contents, sand trap contents, oil-and sludge residues). Category 2 processing facilities have to apply a wastewater pretreatment system removing all animal material with a particle size of > 6 mm.
- Animal manure, contents of gut, stomach and intestines (separated from the intestines), milk and colostrums from animals not suspected to spread any diseases.

Category 3 materials

- All animal materials derived from healthy animals slaughtered for human consumption, which are not intended for human consumption because of being rejected as unfit for human consumption or simply because of commercial reasons.
- Catering waste (with the exception of wastes from international means of transport which is classified as category 1) is also declared as category 3 materials.

**8.2 Compulsory animal by-product treatment & recovery processes**

The ABP regulation (EC) No 1774/2002 assigns to each ABP a compulsory treatment procedure and the corresponding utilisation possibilities according to the 3 categories previously described.

Category 1 Materials

Category 1 materials have to be collected without delay and marked (if possible with smell) or sterilised (50mm, 133°C, 3 bar, 20 min) and marked, followed by incineration in approved incineration plants. With the exception of TSE contaminated-or suspected materials, category 1 materials may also be sterilized (50mm, 133°C, 3 bar, 20 min), marked and buried in approved landfills. Catering wastes from international transportation may be sterilized and buried in approved landfills. Category 1 material may also be processed with other processes to be approved by the scientific committee.

Category 2 materials

Category 2 materials may be incinerated directly, sterilised and incinerated, or may be processed for uses other than animal feedings after sterilisation. For example processing in a biogas, composting or oleo-chemical plant and use as fertilizer, soil conditioner, and for technical products (except medical products). In case of no risk of infectious diseases unprocessed manure, rumen, gut and intestine contents, milk and colostrum may be applied on land, used in an approved pet food plant or used as unprocessed raw material in approved biogas and composting plants. Category 2 materials may also be processed with other processes to be approved by the scientific committee.

Category 3 materials

Category 3 materials may directly be incinerated, may be sterilised, marked and incinerated or buried in an approved landfill. Alternatively, category 3 material may be processed to pet food, pharmaceutical and cosmetic products following appropriate treatment in approved processing plants. Category 3 materials may be further processed in approved biogas and composting plants or in alternative processes approved by the scientific committee. Catering wastes (with the exception of category 1 catering wastes from international means of transport) may be processed in an approved biogas or composting plant according to national legislation.

### 8.3 Animal by-products permitted for bio-treatment

The ABP regulation (EC) No 1774/2002 permits biogas recovery or composting for a variety of animal by-products (table 1). Whether bio-treatment will be applied or not will be determined by the demands of pretreatment, process equipment requirements and allowable use of the end product digestate (compost). Consequently the treatment costs resulting will decide the appropriate allowable process selection.

In principle bio-treatment is not possible for all category 1 materials. As described earlier, only incineration or in some cases burial in an approved landfill are allowed.

All category 2 materials are allowed for bio-treatment provided the animal by-products have been sterilized, marked (smell) and the biogas plant applied has been approved according to article 15, (EC) No 1774/2002. The category 2 materials manure, stomach-and gut contents, milk and colostrum are exempted from the above requirements, provided absence of infectious diseases can be evidenced and the respective biogas plant has been approved according to national legislation.

Furthermore all category 3 materials are allowed for bio-treatment, provided the

biogas plant has been approved according to article 15, (EC) No 1774/2002. Category 3 catering wastes are exempted from this approval and may be applied for bio-treatment in biogas plants according to national legislation based on the requirements of the ABP regulation.

Table 1: Allowable animal by-products to be processed in biogas plants, according. The ABP regulation EC 1774/2002

| **Category** | ***Animal By-product*** | **Requirements** |
|---|---|---|
| 1 | Not envisaged | |
| 2 | Manure, stomach-and gut contents, milk, colostrum, all without any pretreatment | Absence of infectious diseases; Biogas plant approved according to National legislation |
| | All other category 2 materials | Sterilization (133°C, 3 bars, 20 min) and marking; Biogas plant approved according to (EC) No 1774/2002, article 15 |
| 3 | All category 3 materials | Biogas plant approved according to (EC) No 1774/2002, article 15 |
| | Catering waste except category 1 catering wastes | Biogas plant approved according to national legislation (according to (EC) No 1774/2002) |


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### 8.4 Practical approach with allowable category 2 and 3 materials

Manure, stomach and intestine contents, milk and colostrum are classified in category 2. These materials or mixtures of them with other biogenic wastes or raw materials (energy crops, silage) not covered by the ABP regulation, may be processed in biogas plants without pretreatment. The fermentation end product is classified as "manure" and may be used and applied on farm or pasture land like unprocessed manure without having to meet any requirements from this regulation. To prevent unwanted uptake by ruminants, with the exception of manure (or manure derived digestate), all organic fertilizers are prohibited for application on pasture land (Article 22 [1], (EC) No 1774/2002). A forthcoming new European Regulation, (SANCO/2380/2003) will lay down the pretreatment requirements for the application of manure and organic fertilizers (derived from ABP) on farm or pasture land. As long as the manure (digestate) is not traded [1] or placed on the market [2], no further restrictions can be drawn from the ABP regulation.

If manure or manure-derived end products are placed on the market, the ABP regulation defines additional hygienic requirements. A heat treatment of 60 minutes at 70°C or an equivalent treatment according to article 33 (2) (EC) No 1774/2002 is obligatory. End products must be free from Salmonellae (absence in 25 g of end product) and Enterobacteriaceae (less than 1,000 colony forming units per g end – product).

As indicated earlier, catering waste is classified as category 3 materials in the ABP regulation.

Catering wastes are defined as waste food (including used cooking oil) originating from household kitchens, as well as catering services and restaurants. Catering wastes from international means of transport are classified as category 1 material and have to be disposed of.

Until the Commission decides to lay down other regulations, catering waste (category 3) or mixtures with manure may be processed in biogas or composting plants approved in accordance with national legislation. In this case the national authority may derogate from the requirements laid down in the Regulation (EC) No 1774/2002 if the process guarantees an equal reduction of pathogens.

The use of catering waste as swill for pig feeding is prohibited (Article 22, (EC) No 1774/2002). Only Germany and Austria may derogate there from until October 2006 under very strict treatment and control measures.

Anaerobic digestion of catering wastes may therefore possibly increase considerably.

### 8.5 Approval requirements for biogas plants according to article 15, Regulation (EC) No 1774/2002

Biogas or composting plants processing and converting animal by-products have to be approved in accordance with article 15 of the regulation (EC) No 1774/2002. Biogas and composting plants treating only manure, stomach and intestine contents (separated from stomach and intestines), milk, colostrum (category 2) or catering waste and substrates not covered by the ABP-regulation may partly derogate from the requirements for the approval of the plant and the requirements for the corresponding fermentation end product.

Article15 demands 5 major conditions to be fulfilled for bio-treatment plants.

trade means: trade between Member States in goods within the meaning of Article 23(2) of the Treaty placing on the market means: any operation the purpose of which is to sell animal by-products, or products derived there from covered by this Regulation, to a third party in the Community or any other form of supply against payment or free of charge to such a third party or storage with a view to supply to such a third party

I.) meet the requirements for the approval of biogas or composting plants (Annex VI, Chapter II, Part A);

II.) handle and transform animal by-products in accordance with the hygiene requirements and processing standards
(Annex VI, Chapter II, Parts B and C);

III.) be checked by the competent authority (in accordance with article 26);

IV.) establish and implement methods of monitoring and checking the critical control points and V.) ensure the digestion residues and compost, as appropriate, comply with the microbial standards
(Annex VI, Chapter II, Part D).

These major conditions requested are laid down specifically. Among these are most important:

1.) Biogas plants must be equipped with: a pasteurisation / hygienisation unit, which cannot be bypassed with; adequate facilities for cleaning and disinfecting vehicles and containers on leaving the biogas plant. However a pasteurisation / hygienisation unit is not mandatory for biogas plants that transform only animal by-products that have undergone processing method 1 (i.e. steam sterilisation at 3 bars, $133^0$C for 20 min).

2.) Each biogas plant must have its own laboratory, or make use of an external laboratory. The laboratory must be equipped to carry out the necessary analysis and approved by thecompetent authority.

3.) Only the following animal by-products may be transformed in a biogas or composting plant:

a.) Category 2 material when using processing method 1 (steam sterilisation: 50mm, 133°C, 3bar, 20 min) in a category 2 processing plant;

b.) Manure and digestive tract content and

c.) Category 3 material.

4.) Animal by-products must be transformed as soon as possible after arrival. They must be stored properly and treated.

5.) Containers, receptacles and vehicles used for transporting untreated material must be cleaned in a designated area. This area must be situated or designed to prevent risk of contamination of treated products.

6.) Preventive measures against birds, rodents, insects or other vermin must be taken systematically. A documented pest control programme must be used for that purpose.

7.) Cleaning procedures must be documented and established for all parts of the premises.
Suitable equipment and cleaning agents must be provided for cleaning.

8.) Hygiene control must include regular inspections of the environment and equipment. Inspection schedules and results must be documented.

9.) Installations and equipment must be kept in good state of repair and measuring equipment must be calibrated at regular intervals.

10.)Digestion residues must be handled and stored at the plant in such a way as to precluderecontamination.

11.)Category 3 material used as raw material in a biogas plant equipped with a pasteurisation/hygienisation unit must be submitted to the following minimum requirements: a.) maximum particle size before entering the unit: 12 mm b.) minimum temperature in all material in the unit: $70^0$C and c.) minimum time in the unit without interruption: 60 minutes

## Utilization of biogas – Present and future

Biogas is available from landfill sites, wastewater treatment plants, agricultural and livestock operations, food processing plants, gasified woody biomass, or other sources of organic waste. The combustible portion of the gas is methane (CH4).

Most of the rest is CO2, with small amounts of nitrogen, oxygen, hydrogen, water (the biggest source of problems in biogas applications), hydrogen sulphide and trace elements.

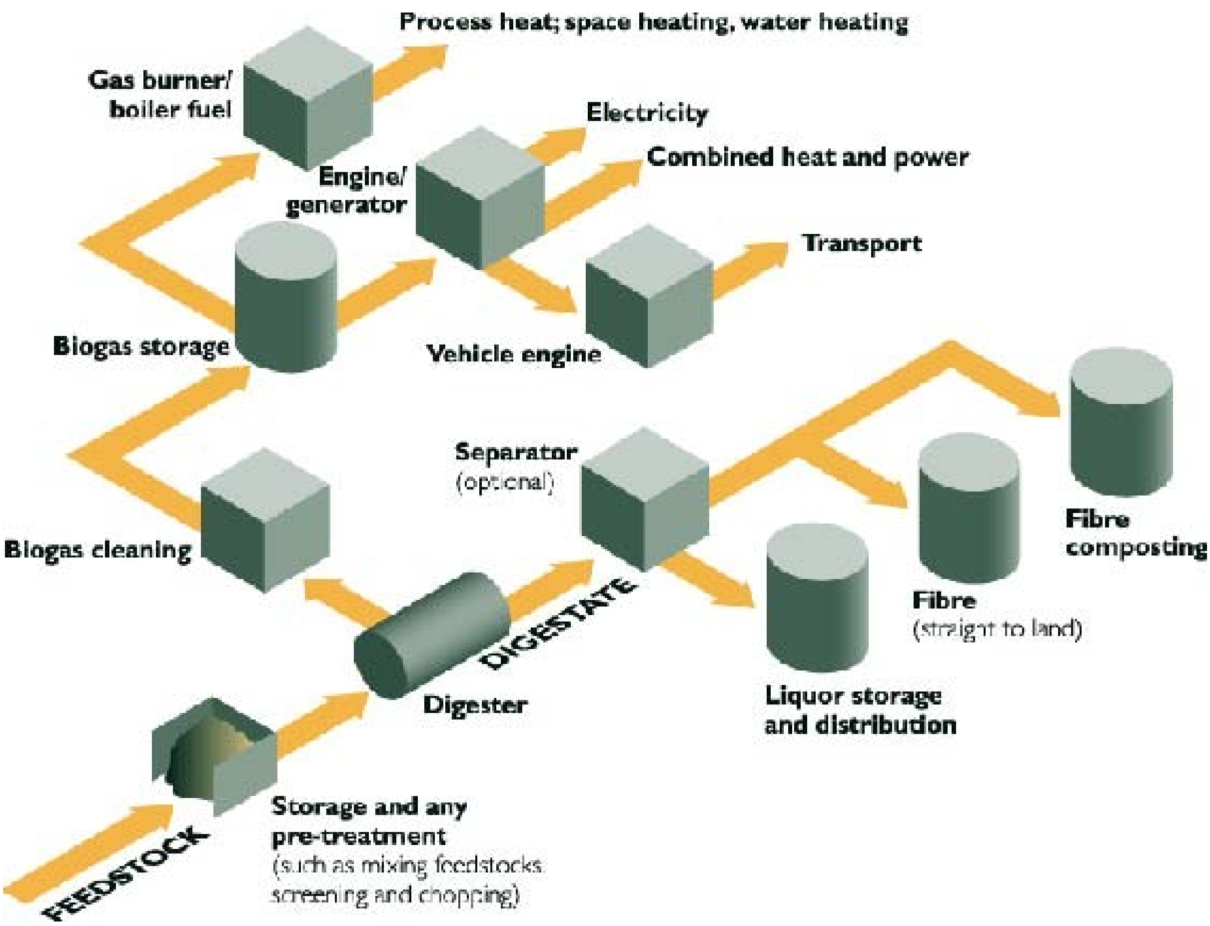


Figure 6: Overview of the biogas utilization process

**BASIC TECHNOLOGIES FOR THE UTILIZATION OF BIOGAS ARE AS FOLLOWS:**

**1. Heat Production**

Medium-calorific heating value-biogas can be used in a number of ways. (Domestic, Industry, Agriculture, district heating) Typically after condensate and particulate removal, the biogas is compressed, cooled, dehydrated and then be transported by pipeline to a nearby location for use as fuel for boiler or burners. Minor modifications are required to natural-gas-fired-burners when biogas is used because of its lower calorific heating value. Another alternative for biogas applications is to generate steam using a boiler onsite. The biogas, after condensate and particulate removal and compression, is burned in a boiler. The customer for this steam would need to be close to the site since high pressure steel insulated pipeline is expensive and heat is lost during transport. Heat production is the simplest and most common application for biogas. The combustion of biogas gives rise to low emissions of nitrogen oxides of about 35-50mg/MJ, which is around half the level for oil combustion.

**2. Generation of Electric Power using reciprocating engines, gas turbines, steam turbines, Microturbine, and Fuel Cell**

Electricity generated on-site using a reciprocating engine, steam turbine, or gas turbine, is being actively used. When a reciprocating engine is used, the biogas must have condensate and particulates removed. In order to move fuel gas into a gas turbine combustion chamber, the biogas must have most of the visible moisture and any particulates removed and then compressed. Using a steam turbine requires generating the steam first. Microturbine can be used to generate electricity at a capacity as small as 30 kW. However, issues exist in the high cost for biogas clean up and limited engine-running time when a Microturbine is applied. The microturbine technology has not been commercialised. High cost associated with biogas clean up is also an important issue for potential application of the fuel cell technology.

Fuel Cells are power-generating systems that produce DC electricity by combining fuel and oxygen (from the air) in the electrochemical reaction. In a first step the fuel is transformed into hydrogen either by a catalytic steam reforming conversion or by a (platinum) catalyst. The H2 is converted to direct electrical current. The by-products of the reaction are water and CO2.

Conversion efficiency to electricity is expected to exceed 50%. However, this is to be noticed, that these options are expensive, and not affordable for a small biogas plant production.

**3. Combined Heat and Power Production (CHP)**

The combined production of power and heat is commonly encountered alternative to heat production alone. The split between the amount of electricity and heat produced is determined by the design of the plant, but the normal value is about 35% electricity and 65% heat with a total efficiency of about 90%. In the case of CHP production, the biogas must be drained or dried, but in case, the soot emitted must be trapped and certain corrosive components, such as hydro-sulphuric acid and chlorinated hydrocarbons must be separated off

**4. Vehicle fuel**

The utilization of biogas as vehicle fuel uses the same engine and vehicle con-figuration as natural gas. However, the gas quality demands are strict. With respect to these demands the raw biogas from a digester or a landfill has to be upgraded. In practice this mean that carbon dioxide, hydrogen sulphide, ammonia, particles, trace components and water have to be removed so that the product gas for vehicle fuel use has a methane content above 95%. A number of biogas upgrading technologies, such as Selexol, Water Absorption, Chemical Absorption, and Pressure Swing Absorption (PSA) have been developed for the treatment of biogas. Using biogas in towns as a fuel for vehicles such as buses, taxis and communal vehicles can make economic sense and has evident environmental advantages.

**5. Injection into an existing natural gas pipeline**

Biogas can be upgraded into high-calorific heating value gas and injected into a natural gas pipeline. As compared with other power generation alternatives, the capital cost for sale of upgraded pipeline quality gas is high because treatment systems that are used to remove CO2 and impurities are required. Also, upgraded gas needs a significant amount of compression to conform to the pipelines pressure at the interconnect point. However, the advantage of pipeline quality gas technology is that:

- the biogas is the only way to produce renewable natural gas, -biogas may supply 10 to 30% of natural gas needs across Europe

- biogas can contribute to the security of gas supply in Europe


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- biogas is also well distributed, so that the grid would be less vulnerable to any crisis

- it is easier to transport the energy into the cities than cities to the energy.

**6. Conversion to other chemical forms**

It is possible to convert the biogas to another form such as methanol, ammonia, or urea. Of these three options, conversion to methanol is the most economically feasible. In order to convert high methane content gas to methanol, water vapour and carbon dioxide must be removed. In addition, the gas must be compressed under high pressure, reformed, and catalytically converted. This tends to be an expensive process, which results in about 67 percent loss of available energy.

**BIOGAS PERSPECTIVES FOR THE FUTURE**

Gases are the fuels of the future. As sources of energy, gases have distinct advantages over liquid and solid fuels both technically and environmentally. In the ecologically sustainable society of the future, the greater part of waste products will be used for production. Natural gas forms an important bit in the puzzle of this development. That is why we are actively working with other gas fuel projects, both to develop biogas and the use of gas fuels. Apart from natural gas we can, to a limited extent today, offer our customers biogas.

**Development towards hydrogen** (Source: SYDGAS)

Hydrogen is expected to be an important energy source in the future. It is produced from water and electricity made from biogas, wind power or solar energy.

Areas where hydrogen can be a significant carrier of energy are things like:

- vehicle fuel
- raw material and fuel for industry
- fuel for generation of electricity
- fuel for heating and cooling buildings

There are many indications that hydrogen will, in the long term, be the fuel that solves energy requirements in an environmentally viable way.

## Quality management and safe recycling

One of the main aims of today's waste management policies is to reduce the stream of organic waste going to landfills and to recycle the organic matter and the nutrients back to the soil, in a way that is safe for the environment, humans and animals. The modern technologies of manure and biogenic waste treatment and recycling must not result in new routes of pathogen and disease transmission between animals, humans and the environment or in organic and inorganic contamination of soil and water. Safe recycling of AD residues implies comprehensive quality management measures, implemented as an integrate part of national waste policies.

## OUALITY MANAGEMENT OF DIGESTATE: THREE MAIN LEVELS

The quality management of digestate refers to the three main levels of the AD cycle (figure 1):

A: Quality management of feedstock

B: The Biomethanization AD process

C: Digestate declaration and optimal utilisation as fertiliser

The main issues of quality management are related to the control of chemical pollutants (organic and inorganic), breaking the chain of diseases transmission by inactivation of pathogens and other biological hazards, removal of physical impurities and nutrient declaration and recycling.

## QUALITY MANAGEMENT OF FEEDSTOCK

This is one of the most important steps in ensuring a high quality end product (digestate), suitable for a safe recycling as fertiliser.

Most common categories of feedstock for anaerobic digestion are:

- Vegetable biomass from agriculture
- Animal manure and slurry
- Digestible organic wastes of vegetable and animal origin from food industries.
- Organic fraction of household waste / food remains, of vegetable and animal origin.
- Sewage sludge


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Before being supplied to the AD plant, each type of biomass must be analysed and characterised concerning:

- Origin (the name and address of the company producing the waste), description of the process, the raw or processed materials the waste originates from, amounts available and the security of supply.
- In case of household waste, the area of collection, if source separated or not and the collection recipients (plastic bags, paper bags, bins, other).
- Declaration of the content of macro and micro-elements, heavy metals, persistent organic compounds, pH, dry matter etc.
- Organoleptic description (colour, texture, smell etc.).
- Eventual hazards related to handling or to the utilisation as soil fertiliser /soil conditioner.

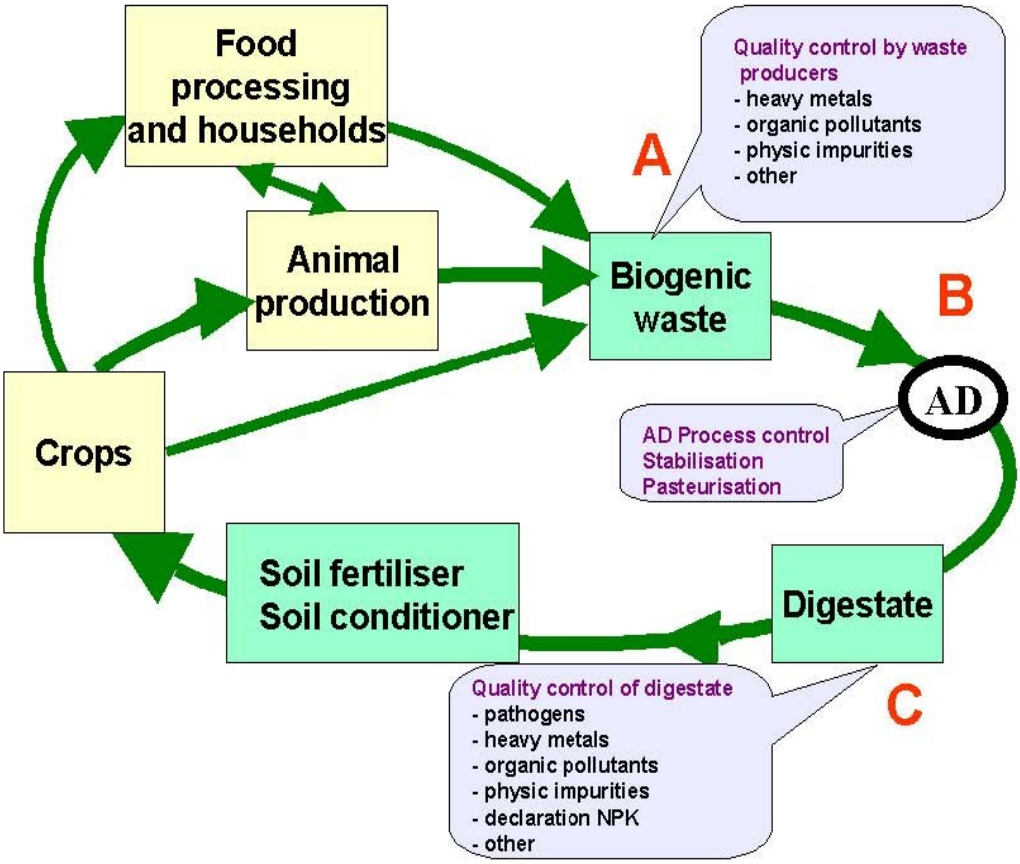


Figure 7: Schematic representation of the closed cycle of anaerobic digestion of biogenic waste and the three main steps (A, B and C) of the quality management of digestate.

## MANAGEMENT OF CHEMICAL CONTAMINANTS

1. Inorganic contaminants/ heavy metals

Heavy metals are elements having atomic weights between 63 and 200. When inappropriately managed, digestate applied as fertiliser may transport dissolved heavy metals to agricultural fields. The presence of heavy metals in digestate occurs from natural and anthropogenic sources. Of particular concern for digestate are: cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), copper (Cu), nickel (Ni), zinc (Zn). Cadmium e.g. may be incorporated into plant tissue. Accumulation usually occurs in plant roots, but may also occur throughout the plant.

Excess metal levels in soils, surface and ground water may represent a health risk, by direct or indirect toxicity, cause eco-toxicity and environmental accumulation. The toxic effect depends on concentration, biological availability and varies with species differences. Slightly elevated metal levels in natural waters for example may cause sub-lethal effects in aquatic organisms such as: histological or morphological change in tissues, suppression of growth and development, changes in circulation, enzyme activity and blood chemistry, change in behaviour and reproduction etc.

| Country/ Region | Cd | Pb | Hg | Ni | Zn | Cu | Cr |
|---|---|---|---|---|---|---|---|
| EU, recommend. | 20 | 750 | 16 | 300 | 2500 | 1000 | 1000 |
| EU, maximum | 40 | 1200 | 25 | 400 | 4000 | 1750 | 1500 |
| Austria | 4 | 500 | 4 | 100 | 1000 | 400 | 150 |
| Belgium | 6 | 300 | 5 | 50 | 900 | 375 | 250 |
| Denmark | 0.8 | 120 | 0.8 | 30 | 4000 | 1000 | 100 |
| Finland | 1,5 | 100 | 1 | 100 | 150 | 600 | 300 |
| France | 20 | 800 | 10 | 200 | 3000 | 1000 | 3000 |
| Germany | 10 | 900 | 8 | 200 | 2500 | 800 | 900 |
| Ireland | 20 | 750 | 16 | 300 | 2500 | 1000 | 1000 |
| Italy | 20 | 750 | 10 | 300 | 2500 | 1000 | - |
| Luxemburg rec. | 20 | 750 | 16 | 300 | 2500 | 1000 | 1000 |
| Luxemburg max. | 40 | 1200 | 25 | 400 | 4000 | 1750 | 1750 |
| Norway | 4 | 100 | 5 | 80 | 1500 | 1000 | 125 |
| Spain (pH< 7) | 20 | 750 | 16 | 300 | 2500 | 1000 | 1000 |
| Spain (pH> 7) | 40 | 1200 | 25 | 400 | 4000 | 1750 | 1200 |
| Sweden | 2 | 100 | 2.5 | 50 | 800 | 600 | 100 |
| Switzerland | 5 | 500 | 5 | 80 | 2000 | 600 | 500 |
| The Netherlands | 1,25 | 100 | 0,75 | 30 | 300 | 75 | 75 |
| United Kingdom | - | 1200 | - | - | - | - | - |

Table 2: Example of concentrations limits of heavy metals in sewage sludge (mg/kg) for application on farmland in different European countries.

## 2. Persistent organic contaminants (organic xenobiotic substances)

The persistent organic compounds of xenobiotic origin represent a hazard to humans, environment and plants due to their toxicity and other environmental adverse effect. Numerous xenobiotic organic compounds are known to have estrogenic effect on vertebrates (xenoestrogens) or to be endocrine disruptors and are considered to be responsible for decline in human male reproductive health as well as for a number of forms of cancer in humans. The hazard effect is related to their volatility, mobility and water solubility, persistence/low biodegradability and bio-availability.

AD residues, composted materials and waste derived products can contain persistent organic contaminants according to the origin of their base ingredients. Agricultural wastes can contain pesticide rests, antibiotics and other medicaments. Industrial organic waste, sewage sludge and household waste can contain aromatic, aliphatic and halogenated hydrocarbons, organo-chlorine pesticides, PCBs, PAHs etc. Some of the most frequent organic contaminants are:

←• PAH (Polycyclic aromatic hydrocarbons). Mainly found in smoke from incineration and the exhaust fumes from vehicles. They deposits on roofs and road surfaces, from where they are flushed into the sewage sludge systems by rainwater.

←• DEPH (Di (2-ethylhexyl) phthalate). The compounds are primarily used as plastic softeners, especially of PVC (e.g. tarpaulins, toys, cars and vinyl flooring). By washing, the substance ends up in the sewage system.

←• LAS (Linear alkyl benzene sulphonates). Primarily used as surfactants in detergents and cleaning agents.

←• NP and NPE (Nonylphenol and nonylphe-nolethoxylates with 1-2 etoxy groups). Typically used as surfactants in detergents, cleaning agents, cosmetic products and vehicle care products. They find their way into the sewage system via wastewater from laundries and vehicle workshops and from cosmetics in household waste and sewage.


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Table 3: Example of limit values for persistent organic pollutants in Hungary

| | Mg/Kg Dry Matter |
|---|---|
| LAS | 1300 |
| PAH's | 3 |
| NPE | 10 |
| DEPH | 50 |

The problem related to the control and management of the organic contaminants in digestate is that it is difficult to perform a screening of such a broad spectrum of contaminants at a reasonable cost. The most feasible way to deal with the problem is the feedstock quality control. Combined aerobic-anaerobic treatment of substrate is also largely utilised today in composting systems and in some cases in AD systems, as a post-treatment step.

Laboratory trials on the four groups of organic contaminants listed above show that a certain reduction of some of the persistent organic contaminants can occur during the anaerobic digestion [5]. Some conditions must be fulfilled: the presence of a relevant micro flora (bacteria populations), optimal life conditions for the relevant micro flora, the accessibility of persistent organic compounds to bacteria population, an adaptation period and a rather constant supply of the organic matter to the reactor. The reduction of LAS and NPE seems to be more effective than the reduction of DEHP and PAH's. The issue still requires further research based on full-scale trials.

**3. Management of physical impurities**

Physical impurities are considered all the non-digestible materials as well as the digestible and low–digestible materials, due to their particle size. Physical impurities are likely to be present in all kinds of biomass feedstock, but most frequently in household wastes, food waste, garden waste, straw, solid manure and other solid types or waste. The most common physical impurities are: plastic and rubber, glass, metal, stones, sand, larger particle size of digestible materials (roots, wood, bark etc.), other physical contaminants. Their presence in feedstock can cause fouling, obstruction and heavy wear of the plant components, disturb the operational stability and cause economic losses while their presence in digestate can cause aesthetic damage, pollution and trauma to the environment (PVC and other plastics, glass and metal etc.).

The removal of physical impurities increases the public acceptance of the digestate as fertiliser and is mainly a matter of ensuring a high physical quality of the feedstock. This can be done either by source sorting or by on site separation (mechanically, magnetically or other). The feedstock can be collected through public or private systems of collection. The separation of the digestible fraction can be done already in the collection phase or it can be done later, using the known waste separation technologies.

Source sorting The separate collection and source sorting is the method that gives a good feedstock quality and excludes contamination from other materials. Separate collection can be done in recyclable paper bags or in plastic bags (biodegradable or not). The collection in nondegradable plastic bags requires on site separation step, for the removal of the rests of plastic bags and lost of biodegradable matter, removed together with the plastic impurities.

On site separation The extent of the on site separation depends of the waste collection method (separate or bulk) and the purity and the type of the collected waste. On site separation does not provide the same waste quality as the source sorted separate collection and can be more costly. It usually is part of a pre-treatment process.

## MANAGEMENT OF BIOLOGICAL CONTAMINATION

The main biologic contaminants in AD substrates are various types of bacteria, viruses, intestinal parasites, prions and other contaminants. The modern technologies of manure and biogenic waste treatment should not result in new routes of pathogens and diseases transmission between animals, humans and the environment. Some main measures would contribute to ensuring a veterinary safe recycling of digestate:

- Livestock health control. No animal manure and slurries will be supplied from any livestock with health problems.
- Feedstock selection and control. Hazardous biomass types are excluded from anaerobic digestion and canalised towards suitable, safe disposal methods (table 3).

- Pre-treatment/sanitation of feedstock [7]
  - -Pressure sterilisation: 133$^0$C, 3 bar, for 20 minutes.
  - -Pasteurisation: 70$^0$C, for 1 hour.
- Regularly control of the efficiency of pathogen reduction measures in digestate.

## EUROPEAN HEALTH RULES CONCERNING ANIMAL BY-PRODUCTS NOT INTENDED FOR HUMAN CONSUMPTION

Many countries enforced national veterinary legislation regarding pathogen control in digestate, but in order to ensure an unique European legislation and by this the same safety measures and quality standards all over Europe, a common EU regulation was adopted "laying down the health rules concerning animal by-products not intended for human consumption".

| Category and description | Rules for utilisation |
|---|---|
| **1.** Animals suspected to be infected with TSE, specific risk material.<br>- Animals, other than farm and wild animals, spec. pets, zoo and circus animals.<br>- Catering waste from means of transport operating internationally | Always destruction incineration |
| **2.** Manure from all species and digestive tract content from mammalians.<br>- All animal materials collected when treating wastewater from slaughterhouses or from category 2 processing plants, except from cat.1 slaughterhouse wastewater treatment plants.<br>- Products of animal origin, containing residues of veterinary drugs. Dead animals, others than ruminants. | For AD must be pressure sterilised, for 20 minutes at 133$^0$C and 3 bars.<br><br>NB: Manure and digestive tract content can be used for AD without pre-treatment. |
| **3.** All parts of slaughtered animals, declared fit for human consumption, or not affected by any signs of diseases.<br>- Hides, skins, | For AD must be sanitised in separate tanks for 1hour at 70 $^0$C. |

The document outlines the methods and sanitary measures regarding the treatment of animal waste and the criteria for the future regulation of this area. Apart from this, a second draft of a working document concerning the biological treatment of biowaste, regulating the treatment and utilisation of all kinds of organic waste is about to be elaborated by the Commission.

The aim of these documents is to promote the biological treatment of organic waste by harmonising the national organic waste management measures, to prevent any negative impact on the environment and to ensure that the use of treated and untreated organic waste results in benefits for the agriculture and ecological improvement, to ensure the functioning of the internal market and to avoid obstacles to trade and distortion and restrictions of competition.

## UTILISATION OF DIGESTATE AS FERTILISER AND NUTRIENT MANAGEMENT

### Sampling, analysing and product declaration of digestate

To be recycled as fertiliser, digestate must have a defined content of macronutrients. Average samples of digestate must also be analysed for heavy metals and persistent organic contaminants, making sure that these are not exceeding the detection limits permitted by law.

### Nutrient load per hectare

The application of digestate must be done on the basis of a fertiliser plan, elaborated for each agricultural field and can be a wide variety for the West Transdanubian or the Central East Hungarian region with more sandy soils. The experience shows that an environmental and economic suitable application of digestate fulfils the phosphorus requirements of the crops and completes the nitrogen requirements from mineral fertiliser.

Inappropriate handling, storage and application of digestate as fertiliser can cause ammonia emissions, nitrate leaching and overloading of phosphorus. The nutrient loading on farmland is various regulated in different countries (table 4). The EU nitrate-directive (91/676/EEC nitrate) regulates the input of nitrate on farmland, aiming to protect the ground and surface water environment from nitrate pollution.

Maximum nutrient load Required storage compulsory season (Kg N/ha y) capacity for spreading.


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## CONCLUSIONS

The quality management of the anaerobic digestion residues implies quality control of the three main chains of the biomethanisation-AD cycle: the feedstock, the digestion process, and the digestate. This is done by some main measures:

- Selection/excluding from AD of the unsuitable waste types / loads, based on the complete declaration of each load: origin, content of heavy metals, persistent organic compounds, pathogen contamination, other potential hazards etc.
- Source sorting and separate collection of digestible wastes, preferably in biodegradable recipients.
- Periodical sampling and analysing of the biomass feedstock.
- Extensive pre-treatment/on site separation (especially for unsorted waste).
- Pre-treatment for safe veterinary recycling
- Process control (temperature, retention time etc.) to obtain a stabilised end product.
- Periodical sampling, analysing and declaration of digestate.
- Handling, storage and application of digestate after a fertilisation plan throughout “good agricultural practice”.

## SAFE RECYCLING OF DIGESTATE

### Good agricultural practice

- Source sorting and separate collection of digestible wastes, preferably in biodegradable recipients.
- Selection / excluding from AD of the unsuitable waste types / loads, based on the complete declaration of each load: origin, content of heavy metals and persistent organic compounds, pathogen contamination, other potential hazards etc.
- Periodical sampling and analysing of the biomass feedstock.
- Extensive pre-treatment/on site separation (especially for unsorted waste).
- Process control (temperature, retention time etc.) to obtain a stabilised end product.
- Pasteurisation / controlled sanitation for effective pathogen reduction.
- Periodical sampling, analysing and declaration of digestate.
- Including digestate in the fertiliser plan of the farm and using a "good agricultural practice" for application of digestate on farmland.

## Guidelines for optimum use of digestate

The guidelines are based on several years' field trials and experience achieved by advising the many farmers.

- As a principal rule, digestate should only be applied at the start of the growing season, in March and April, and later on, only in vegetative growing crops.
- By the establishment of spring-sown crops, the digestate must be incorporated into the soil immediately after it has been applied. The time from application to incorporation must be as short as possible, to minimise ammonia volatilisation. The best thing to do is to simultaneously spread and incorporate the digestate.
- In over wintering crops, the crop must be started with one third of the total N-requirement in mineral fertiliser. The best utilisation of the digestate in over wintering crops is achieved in the period mid spring to early summer, when the crops are in

vigorous vegetative growth. To make the digestate infiltrate quickly into the soil, dragging hose-equipment must be used. The most suitable crops for digestate utilisation are: Winter wheat, winter barley, winter rye and winter rape. Digestate can supply 50-70% of their N-requirement.

- The risks of ammonia volatilisation from digestate is rather high and can be reduced by using the right equipment -dragging hoses -and by taking the weather into consideration. During storage, handling and spreading it is important to take the ammonia volatilisation into consideration.

To minimise the ammonia volatilisation, during the storage and spreading of digestate, some general guidelines should be followed:

- Always have a covered or a floating layer on the storage tank.
- Avoid stirring by always pumping from the bottom of the tank.
- The digestate should only be stirred just before application.
- Place storage tank where they are sheltered from wind and.
- Inject or incorporate the digestate in the topsoil immediately after application.
- Use dragging hoses when digestate is applied in growing crops (figure 4)
- Apply digestate only under optimum weather conditions: cool, humid and no wind.

There is a possibility to acidify the digestate when applied. This decreases the pH-value and thereby the liability of ammonia to volatilise.

**Practical guidelines for planning a biogas plant**

## KEY PRECONDITIONS FOR DEVELOPMENT

The main precondition for building a biogas plant is the existence of accessible, digestible biomass feedstock. This means that the biogas plant must be located in areas with high livestock density and easy access to industrial organic waste. The second most important precondition is to have a market for energy sale.

Some of the indispensable elements of the decision process are:

- The identification and the evaluation of the amount and the security of supply of digestible biomass resources in the area and the elaboration of a plan for biomass supplying.
- The existence and the evaluation of the potential market for energy sale (heat and electricity).
- Possibilities to get a favourable financing scheme (long term, low interest loans, grants etc).
- Careful evaluation of the environmental and socio-economic impacts (increased transport, odours, employment etc.) and of the public acceptance of the biogas plant.
- A general outline of the operational budget (main costs and income sources).

## THE PLANNING ACTORS

The actors involved in planning a medium and large scale biogas plant are usually the farmers as slurry suppliers, the organic waste suppliers, the energy consumers, local authorities and decision makers, biogas planners and consultancy companies, biogas plant suppliers companies, financing companies, investment companies etc. The actors involved in planning a small scale biogas plant in Hungary are far more few, as supplier and consumer is te farmer self.


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## ORGANIZATION AND FINANCING

It is highly important that the planning phase does not exclusively concern the technical assessment but also focuses on the organisation and financing of the project. In connection with the assessment of the organisation, decisions should be made concerning the organisation both in the initial phase and in the operating phase. In the initial phase the choice roughly lies between two types of organisations:

I. The biogas plant can be bought by single contractor. However, if this done so, the plant might not be affordable for an Hungarian small scale farmer. The builder (builder's consultant) invites tenders for the whole contract from either domestic or international contractors. The advantage is that the project is bought at a fixed price but the disadvantage is that it is difficult to determine how the plant is constructed and to calculate the impact on local employment.

II. The biogas plant can alternatively be established as an ordinary building project. This means that builder's consultant designs the plant in detail and afterwards tenders are invited for part contracts. The advantage is that the builder gets a comprehensive insight into the construction of the plant and that the local impact on employment can be affected. Normally this method of calling in tenders results in cheaper plants. The disadvantage can be some uncertainty about the price.

The third alternative in Hungary is, that based on advisers support, the farmer is building the plant himself (low cost version), which is the most realistic viability for most small farmers, with considerations of the financial barriers for obtaining grants.

In the building phase the definition of organisation can be postponed until the closing of a contract on consultancy. The plant can be owned and operated by an existing organisation

(e.g. a larger company, power companies or public authorities). Usually it will be necessary to form a new organisation consisting of the involved parties. The organisation must observe the following objectives:

- achieve sufficient security for the economy of the company
- secure coherence between assumption of risk and the profit potentials

- secure coherence between influence on decisions in the organisation and profit potentials.

The chosen organisation, participants and especially the financial commitment of the participants in the project are of considerable importance for achieving satisfactory financial arrangements.

If the project is established and operated by a large well-consolidated company, the company will provide the required security. If the organisation is formed with the explicit purpose to establish and operate the plant, it may some times be difficult to establish the required security. In this case the measures are:

- invested capital from the participants
- sum guaranteed
- public guarantees secured because of the socio-economic, local economic and environmental advantages of the project.

The financing will usually be divided into two principal items:

- Grants (national or international)
- Loans (in most cases such is not available for an Hungarian small farmer).

In connection with the assessment of the project it is of course necessary in the business plan to include the costs for financing (interests and repayment). The biogas plant is characterized by very large investments (extensive capital costs) compared to the operating costs. It is therefore necessary to procure financing, which is:

- Long-term (minimum maturity of 10-15 years)
- Loans with as low interests as possible.

As receipts derive sale of energy and possibly manure on ordinary market terms, which must (as a minimum) be expected to follow the ordinary price development, there will not be any risks involved in financing the plant with index regulated loans.

## KEY ELEMENTS OF CONSTRUCTION

Regardless the supplied types of biomass, any biogas plant will consist of the following main components:

Pre-storage/Receiving equipment: The biomass is received at the plant in pre-storage tank(s) and/or other equipment from which it will be admitted into the digesters. The purpose of the receiving equipments is to facilitate unloading and mixing procedures and to prepare the biomass for admission into the digesters. The pre-storage/receiving equipment must have a capacity which will prevent bottleneck situations from occurring and allow the plant to operate for a few days without further supplies (e.g. in connection with holidays). **Slurry collection pit:** The manure collects and homogenizes in the pit to produce the feedstock for the biogas plant.The size and technical equipment of the pit (mixer, crusher, pumps) depends on the feedstock.

Digesters: The capacity and process temperature of the digesters should allow a stable and efficient process. The tanks should always be heated and insulated so that the temperature can be controlled. In addition to this the digester must be provided with a stirrer, which will secure efficient mixing of the biomass. **Fermentation tank:** The digester can be of vertical or horizontal type. The digester size depends on the amount of substrate to be digested and the required residence time in the digester. The digester is heated and equipped with an agitator and the required equipment for withdrawing the biogas.

Post -storage tanks: The purpose of the tanks is to operate as buffer tanks so that the plant can maintain production without removing biomass. In addition to this it is possible to extract gas (after digestion). **Post fermentation tank & manure store:** Here the fermentation residue is stocked until spread in the field. The fermentation residue store can be a gas-tight post-fermentation tank from which the biogas produced after the principal fermentation process is collected.

Pipe systems with pumps and valves: The total pipe system required for moving biomass, gas, process heat, etc.

Gas storage: Usually it will be an advantage to have some gas storage capacity before the gas reaches the place of consumption in order to compensate for fluctuations in the gas production. If the settling price of power differs between night and day, a possibility would be


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establish a storage which allows utilization of gas when the power price is at its highest. The gas storage should be constructed as a low-pressure storage. **Gas reservoir:** The gas store is a buffer tank to store the gas until further processing. The gas store can be integrated in the digester or post-digestion tank or it can be set up as a separate unit. Where the gas is stored above the digester or post-digestion tank, these are covered with plastic film under which the gas collects. Otherwise a gas collection bag is installed apart from the digester.

Gas utilization: The gas is best utilized in a gas engine (power and possibly heat production). The power is sold to the mains. The heat can either be used as process heat or converted into cold in an absorption cooler. As an alternative the heat can be emitted. **Combined heat and power unit:** The biogas, from which sulfur and water have been removed, is converted to heat and electricity in the combined power and heat generation plant. About one-third of the energy stored in the biogas is converted to electricity and about two-thirds are converted to heat. The electricity can be fed into the public power grid, the heat is used on the farm or locally.

General conditions for economic viability

The cost of a biogas plant can be calculated by dividing the total investment cost (depreciation, interest) into the lifecycle years of the plant and further considering the cost of connecting the system to the public power grid, current operating cost (maintenance and repairs, operating materials), plus wages (plant operator). This is opposed to the revenue from selling the electricity generated and earnings from the use of fermentation aids. Prospective builders of a biogas plant should also inform themselves of available government subsidies and grants.


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## THE PLANNING TASK

### Feasibility studies

The potentials of a biogas plant can be established in a geographically defined area. The biogas plan may typically consist of the following items:

- mapping of manure resources
- mapping of waste products
- energy production and application/sales of energy
- supply scenarios (alternatives)
- estimate of consequences for the plant
- utilization of the digested product as manure

As an alternative the potentials can be studied based on a specific project. The contents will more or less be identical but be adapted to specific conditions at the site and the required plant concept. Table 1 shows the average biogas potential of the most common AD substrates in Hungary.

### Location of the plant

The projects can be established in connection with a biogas plan or based on knowledge about local conditions. The following conditions must be observed:

- Accessibility to biomass – manure and/or various type of waste
- Possibilities of selling power and possibly heat (either directly or as cooling through absorption coolers)
- Political readiness to establish the project
- Possibilities of financing.

High-rate conversion requires available resources of a minimum of 40 t of biomass/day and a part of the biomass must be procured as high-grade waste products, etc.

Transport of biomass is one of the important operation costs for the biogas plant. Aiming to


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have a sustainable economy for the plant, a thumb rule must be considered: the nutrient value of the digested biomass unit must be at least the same or bigger that the total costs of treatment, storage and transport of the same digested biomass unit. This aspect must be considered when planning the emplacement of the plant in the area as well as the location of the post storage tanks for digested biomass.

When deciding upon the location of a biogas plant, a suitable distance between the plant and the residential areas must be considered as well as the direction of the main winds, in order to minimise traffic and odour nuisances.

**Mapping of resources and energy sale**

The resources are mapped either directly or indirectly. By direct mapping the specific qualities and quantities are examined. It is often possible in industries or other enterprises, which have already established a more or less organized handling of the biomass. Indirect mapping indicates that quantity etc. is estimated from standard figures such as e.g. manure production per cow, waste production per inhabitant, waste quantity per slaughtered animal. The method is particularly suited for mapping of manure and organic household waste. In practice the methods are combined.

The following information about the biomass is obligatory:

- quantity
- quality (content of dry matter and a rough identification of type)
- possible seasonal variations
- present use/disposal (possibly including price of disposal).

**Organisation**

Besides the technical assessments the feasibility study should also contain an assessment of the organisation of the project under establishment and under operating conditions. As biogas projects aim at meeting requirements and solving problems for individuals, companies, groups, etc. it is essential that all interested parties are involved from the first steps of the planning phase.

Based on the interests and potentials of the interested parties the future builder/management organisation can be formed. In some cases the existing organisation is able to handle this task


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but often a completely new organisation is required. The organisation must be described and plans for a possible formation of a new organisation must be started already in the initial phases of the planning.

**Planning tools**

Important planning tools are:

- Model for calculation of the quantity of biomass
- Models for calculation of the potential gas production
- Models for calculation of the investments
- Standard business plan
- Models for calculation of environmental impact
- Models for calculation of optimal utilization of the digested biomass as manure.

And most important:

- Dialogue with the involved parties
- Local adaptation of solutions
- Assessment of political acceptance.

The appendix lists a number of key figures and directions to be used in the planning phase.

These tools and routines can of course be refined and specified into details as required. But it is essential that the planning process starts at an overall level. The first phase will focus on the overall possibilities of establishing the plant. The financial possibilities are often totally indicative for the implementation so a business plan for the plant should already be prepared at this stage – in the introductory phases mainly based on a number of conditions and outlining estimates.

If the investigations indicate that the project is viable, the estimates are calculated into details and the conditions are gradually exchanged with specific knowledge about actual conditions, agreements, etc.

Table 4: Estimated biogas potential of the most common substrates in Hungary

| Biomass | **TS (%)** | **VS/TS** (%) | **VS** (%) | Specific methane potential m3CH4/kgVS | Specific methane production m3CH4/ton |
|---|---|---|---|---|---|
| Cattle manure | 8.00 | 80.00 | 6.40 | 0.200 | 12.8 |
| Pig manure | 5.00 | 80.00 | 4.00 | 0.300 | 12.0 |
| Poultry droppings | 5.00 | 80.00 | 4.00 | 0.300 | 12.0 |
| Mixed manure | 6.50 | 80.00 | 5.20 | 0.250 | 13.0 |
| Solid manure, cattle | 20.00 | 80.00 | 16.00 | 0.200 | 32.0 |
| Solid, manure, pigs | 20.00 | 80.00 | 16.00 | 0.300 | 48.0 |
| Solid manure, poultry | 20.00 | 80.00 | 16.00 | 0.300 | 48.0 |
| Liquid manure, cattle | 3.00 | 80.00 | 2.40 | 0.200 | 4.8 |
| Liquid manure, pigs | 2.50 | 80.00 | 2.00 | 0.300 | 6.0 |
| Stomach/intestinal content, cattle | 12.00 | 80.00 | 9.60 | 0.400 | 38.4 |
| Stomach/intestinal content, pigs | 12.00 | 80.00 | 9.60 | 0.460 | 44.2 |
| Flotation sludge | 5.00 | 80.00 | 4.00 | 0.540 | 21.6 |
| Bleach clay | 98.00 | 40.00 | 39.20 | 0.800 | 313.6 |
| Whey | 5.00 | 90.00 | 4.50 | 0.330 | 14.9 |
| Whey concentrate | 10.00 | 90.00 | 9.00 | 0.350 | 31.5 |
| Jam | 15.00 | 85.00 | 12.75 | 0.330 | 42.1 |
| Alcohol | 40.00 | 95.00 | 38.00 | 0.400 | 152.0 |
| Waste water sludge | 5.00 | 75.00 | 3.75 | 0.400 | 15.0 |
| Refuse | 30.00 | 85.00 | 25.50 | 0,400 | 102.0 |

AD = anaerobic digestion
TS = total solids
VS = volatile solids


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Table 5: General data for small farm scale energy crop Co – digestion plant for Hungary

| | |
|---|---|
| DIGESTER SYSTEM | continuous flow tank reactor |
| MEAN RESIDENCE TIME (d) | 40-50 |
| DIGESTION TEMPERATURE | 55 °C |
| SUBSTRATES | Manure, corn silage, grain |
| BIOGAS USE | Heat generation |
| USE OF DIGESTATE | Fertilizer, farm land |
| INVESTMENT COSTS (HUF/€) | HUF 18 million (estimated for 2007) €75,000 |

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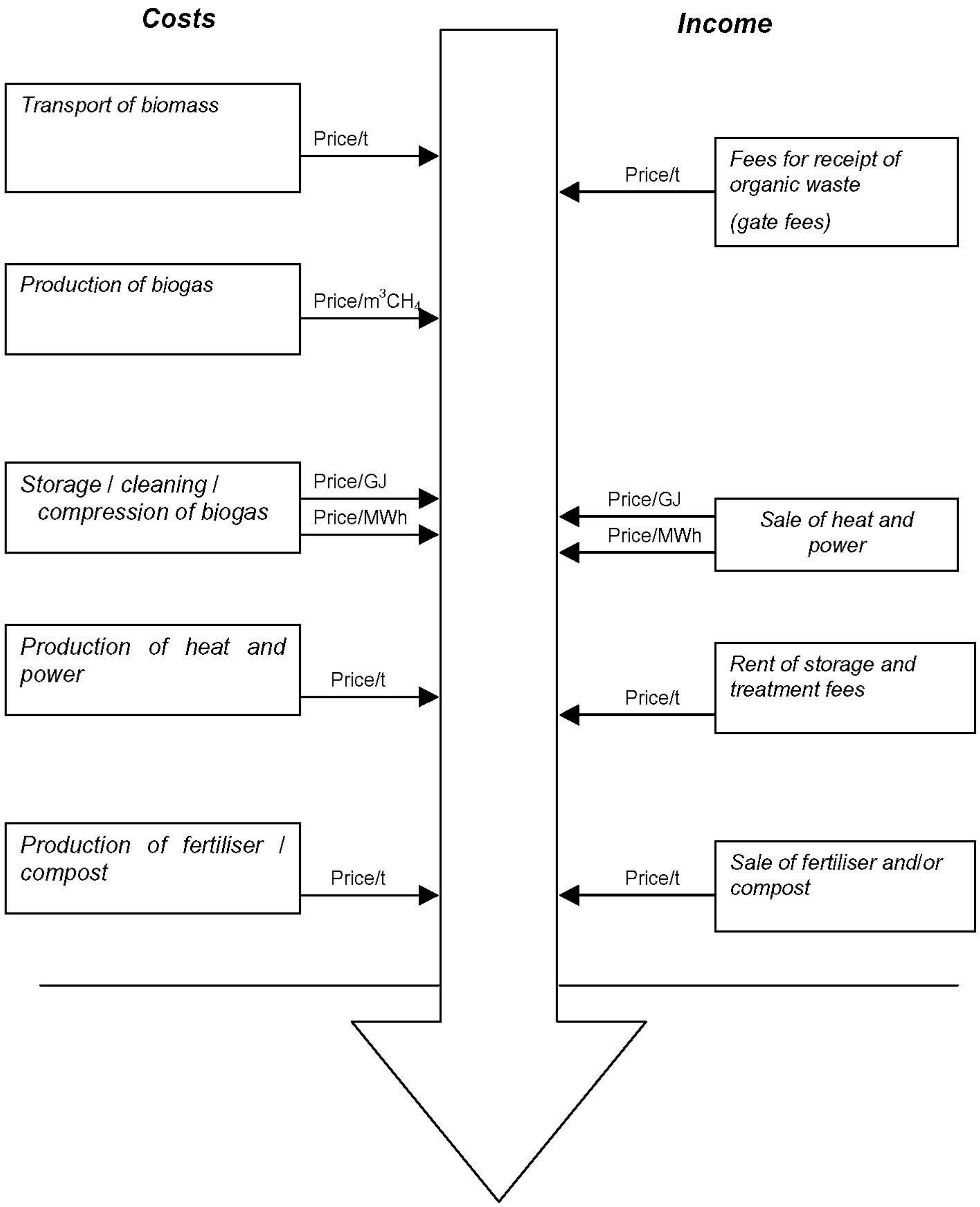
**The economy of the biogas plant**




The key elements of the economy of a biogas plant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