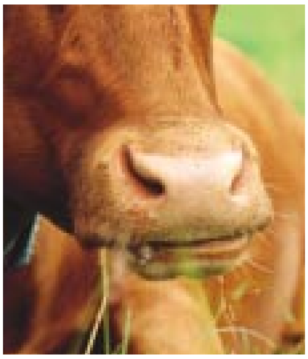
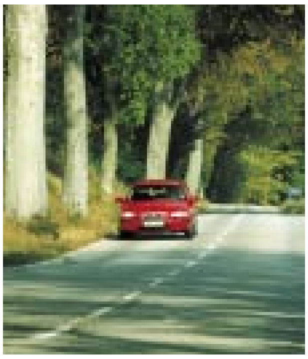
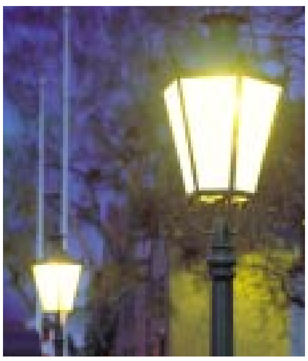




BIO GAS



RENEWABLE ENERGY FROM ORGANIC WASTE

PREFACE

The earth's finite resources should be recycled and utilised to the fullest extent possible in order to promote an ecologically sustainable society in the future. In this respect, biogas will surely play an important role, and the Swedish Biogas Association is working on a broad front to achieve this objective.

The publication in your hands gives an overview of a fascinating world, one in which microorganisms are responsible for producing a valuable resource that we can harvest. We aim to awaken your interest in the possibilites of biogas. We also hope that you will want to gain a deeper knowledge of this subject, and take an active part in the development of biogas as an energy source. We hereby welcome you into the world of biogas. The Swedish Biogas Association will be happy to provide you with any further information that you might need.

Ronald Svensson

Chairman, The Swedish Biogas Association

This publication is a revised version of the brochure "Biogas – or what you can do with rotten apples" by Erik Norin published in 1998 by the Swedish Biogas Association. You can order this brochure by contacting the Swedish Biogas Association at the address given on the back page of this brochure.

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Several members of the Swedish Biogas Association have contributed with opinions and photographs.

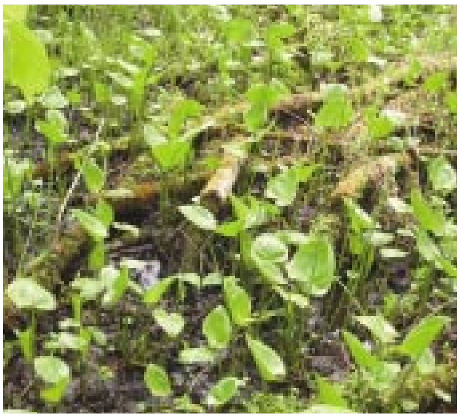
Thanks everyone!

BIOGAS – NATURAL ENERGY

Biogas is formed when microorganisms, especially bacteria, degrade organic material in the absence of oxygen. Production of biogas from the remains of dead plants and other organisms is a natural biological process in many ecosystems with a poor oxygen supply, for example in wetlands, rice paddies, lake sediments, and even in the stomachs of ruminating animals.

The large quantities of organic waste produced by modern society must be treated in some way before being recycled back to nature. Some examples of such organic wastes are sludges from municipal waste water treatment plants, kitchen refuse from households and restaurants, and waste water from the food processing industry. In a biogas process, the natural ability of microorganisms to degrade organic wastes is exploited to produce biogas and a nutrient rich residue which may be used as a fertiliser. The main constituent of biogas, methane, is rich in energy, and has a long history of use by mankind. Nowadays, production of heat and electricity is one of the major applications. As an environmentally-friendly alternative to diesel and petrol, biogas may also be refined to produce vehicle fuel.

This brochure deals primarily with the production and utilisation of biogas under controlled conditions. However, we should keep in mind that the natural production of biogas in different ecosystems greatly exceeds that which is deliberately produced by mankind.



Biogas is formed naturally in many ecosystems with low oxygen supply, for example in bogs and marshes.

Biogas is also produced during the degradation of plant material in the rumen of cows.

THE BIOGAS PROCESS IN SOCIETY

Biogas is produced as a result of the decomposition of organic material in a completely oxygen free (anaerobic) environment. The resulting product is called digestion residue or bio-manure. It is rich in plant nutrients and its high content of organic matter also makes it a valuable soil conditioner for soils of low humus content and poor structure, for example compacted clay soils. The digestion residue can replace the use of manure in farms without livestock, thereby decreasing the need for commercial fertiliser. This will be especially important in ecological farming, where commercial fertilisers are not allowed.

Biogas contains mainly carbon dioxide and energy-rich methane, which is also the main component of natural gas. Carbon dioxide and water vapour are the main products of the combustion of methane. Climate change resulting from global warming (the so-called greenhouse effect) is a major global problem, and the emission of a greenhouse gas like carbon dioxide should therefore be minimised as far as possible. As opposed to the combustion of fossil fuels, such as coal, oil and natural gas, the use of biogas does not contribute to the greenhouse effect, since the carbon in biogas originates from carbon dioxide taken up by plants during photosynthesis. This carbon is already in circulation in the biosphere, so that biogas is considered a renewable energy source.

ORGANIC WASTE BECOMES FERTILISER AND ENERGY

The biogas process has been used by mankind for more than 100 years and improvements are still being made. These efforts are now being intensified due to a ban on depositing organic material in landfills, which begins in Sweden in 2005. The biogas process is of great interest, since by controlling the natural process of biological decomposition, all the nutrients and energy originally present in the organic material are retained. The waste can therefore be considered as a resource, which after anaerobic treatment produces a nutrient-rich residue and renewable environmentally-friendly energy. Nowadays, biogas emissions from existing landfills can also be collected and used. Biogas energy can also be produced from the anaerobic digestion of various crops. This may contribute in the future to increasing energy self-sufficiency and reducing our dependency on oil. Biogas can also be produced from manure from farm animals like pigs and cattle. The residue is nutrient-rich and both easier to handle and more hygienic than the raw manure. The treatment also reduces odours. Ammonia and methane emissions to the atmosphere are reduced if manure is digested in closed tanks instead of conventional storage and handling.

The main use of biogas is as an energy source for the production of heat and electricity. After some pre-treatment, biogas can also be used to supply the gas grid, which will open up several new markets. Biogas is classified as the cleanest fuel on the market and may be used as a vehicle fuel, in exactly the same way as natural gas. Spreading from the south and west of Sweden, the number of filling stations providing methane gas is now steadily increasing.

A KEY LINK IN THE SUSTAINABLE USE OF RESOURCES

The biogas process should constitute an important link between consumption and production in a future society based on long-term sustainable recycling of nutrients and energy. The nutrients present in organic wastes, especially the major nutrients nitrogen, phosphorus and potassium, can be returned to agricultural land, thereby reducing the need for commercial fertilisers, and the by-product methane represents a valuable energy resource. The biogas process will play an increasingly important role in town planning, since it touches on several critical environmental issues related to the sustainable use of resources, such as energy supply, public transport, handling of organic wastes, the interplay between urban and rural areas and the effects of land management on the environment.

The nutrients available in the soil are taken up by plant roots. We consume some plants directly, whereas others are used as animal feed. In this case, soil nutrients and energy are conserved in food products such as meat, butter and eggs.

We do not make use of all the energy and nutrients present in the food. Some remains in household and restaurant wastes.

Nutrients present in the organic waste should be returned to agricultural land. The biogas process is an environmentally-sound way to recycle nutrients via the bio-manure that is produced.

By consuming food, soil nutrients are transferred to our bodies. Food also contains energy, for example in carbohydrates and fats, that we assimilate.

In a biogas process, microorganisms degrade organic waste into simple components. This process is completely anaerobic, that is without any contact with oxygen. Nutrients are concentrated in the residue, whereas almost all the energy is conserved in the final product, methane.

The commonest use of biogas is to make use of its energy to heat buildings or to generate heat and electricity using combustion engines.

Biogas from organic waste may be treated to produce vehicle fuel. The fumes are cleaner compared to diesel exhausts, which is particularly important in urban areas.

FACTS

HISTORY

In a historical perspective, biogas has been produced since the second half of the 19th century. India and China were among the pioneering countries, where biogas produced from manure and kitchen waste has long been used as a fuel for gas cookers and lamps.

In Sweden, biogas has been produced at municipal waste water treatment plants since the 1960's. The primary incentive was to reduce sludge volumes. However, the oil crises of the 1970's rang alarm bells, leading to research and development of biogas techniques, and construction of new plants in order to reduce environmental problems and dependency on oil.

Industry was the first to act : sugar refineries and pulp mills started to use anaerobic digestion for waste water purification in the 1970's and 1980's. At this time, several smaller farm-sized plants were also constructed for anaerobic digestion of manure.

During the 1980's, several landfill plants started to collect and utilise biogas produced in their treatment areas, an activity that expanded quickly during the 1990's. Several new biogas plants have been constructed since the mid-1990's to digest food industry and slaughterhouse wastes, and kitchen wastes from households and restaurants.

BIOGAS GENERATES HEAT AND ELECTRICITY

Locally produced biogas is often used for heating of houses and other localities in the vicinity of the biogas plant.

The high content of methane in biogas makes it a valuable energy source. In this respect, biogas is similar to natural gas, and these fuels can be utilised in the same way. However, biogas must be upgraded, that is refined to remove carbon dioxide, to obtain the same quality as natural gas. When used directly for production of heat or electricity, the treatment of biogas is rather simple, and it is not necessary to remove carbon dioxide.

PRODUCTION OF HEAT

Without a doubt, heat production is the simplest and commonest use of biogas. For this purpose, pre-treatment normally just involves the removal of water. Gas boilers for heat production are found at almost all biogas plants in Sweden, and the gas is frequently used for heating of buildings and households located nearby. Since costs of storage and transport are limited, economic gains can result from using locally-produced biogas for combustion instead of buying in oil. Biogas is therefore a local fuel which is predominantly used in the vicinity of the production plant, although heat produced in excess may be transported to remote localities either directly via pipelines or indirectly via district heating networks. In larger networks, it is usually possible to use biogas as a part of the baseload throughout the year. However, in smaller systems it might be necessary to flare off, that is burn, some of the biogas produced, especially in summer when the demand for heat is low.

COMBINED POWER AND HEAT PRODUCTION

The combined production of power and heat is a common alternative to heat production alone. Here, the energy contained in the gas is most effectively utilised. The pre-treatment includes drainage or drying to remove water vapour. In addition, the gas must be separated from particles and certain corrosive components such as hydrogen sulphide and chlorinated hydrocarbons. At most Swedish biogas plants, electricity is produced in generators driven by gas motors. Although electricity can be produced in many ways, Otto engines are most appropriate for power generation on the scale relevant here. The principle of such a motor is that the gas is compressed using cylinder pistons and thereafter lit by a spark plug. 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, that is the amount of useful energy as compared to the energy originally supplied, of about 90 %.

A CLEAN AND EFFICIENT FUEL

Methane burns with a clear and clean flame, so that gas boilers and other equipment are not contaminated with dust, slag and ash. This leads to a cleaner environment as well as less wear on the plant, which will last longer and cost less in terms of maintenance.

The energy in household waste can be put to use in the kitchen.

The combined production of heat and electricity means that the energy contained in the biogas is most efficiently utilised.

Methane burns with a clean and clear flame. The equipment is not contaminated with ash and dust.

In addition, emissions of environmentally harmful compounds such as sulphuric compounds and heavy metals are negligible. Emissions of allergy and cancer causing agents such as particles and hydrocarbons are also smaller than when coal or oil are used for combustion.

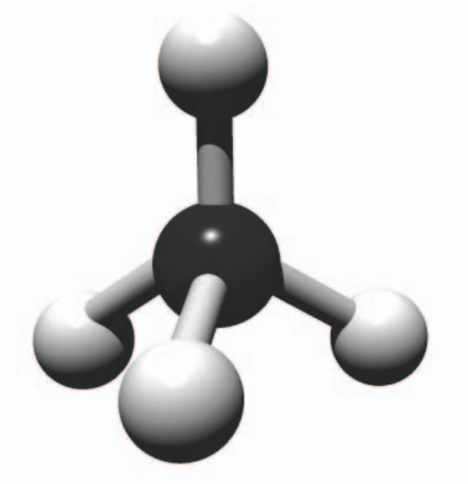
Biogas can also be used efficiently as a fuel. As it is already a gas, air can be more precisely mixed with the biogas, resulting in a more complete combustion than when solid or liquid fuels are used. Due to the low content of sulphur in biogas, a low exhaust temperature can be used, leading

to a high total efficiency. When using more sulphur-rich fuels, such as coal and oil, the exhaust temperature must be kept higher to avoid sulphur from precipitating as sulphuric acid, which might cause damage to exhaust pipes and chimneys. The higher temperature means that some of the energy is lost.

ECONOMIC INCENTIVES

In Sweden, biogas has been exempted from energy tax since 1995. The owner of a biogas plant is also eligible to hold an 'electricity certificate' for every megawatt hour of renewable energy it produces. Such certificates are sold to consumers via electricity distributors, giving the producer extra income. This gives biogas a competitive advantage over non-renewable energy sources such as oil, coal and natural gas. More information about electricity certificates can be found at the home page of the Swedish Energy Agency (www.stem.se).

FACTS
PROPERTIES OF BIOGAS



Biogas consists of 45-85 % methane (CH_4) and 15-45 % carbon dioxide (CO_2), with the exact proportions depending on the production conditions and processing techniques. In addition, hydrogen sulphide (H_2S), ammonia (NH_3) and nitrogen gas (N_2) may be present in small amounts. Biogas is normally saturated with water vapour. Artificially produced methane, for example from wood products by a process called thermal gasification, is sometimes confusingly called biogas. This is also a renewable source of methane, but it is not discussed in this brochure.

The amount or volume of biogas is normally expressed in 'normal cubic meters' (Nm^3). This is the volume of gas at 0 °C and atmospheric pressure. The energy value is expressed in joule (J) or watt hours (Wh). Pure methane has an energy value of 9.81 kWh/Nm^3 (9810 Wh/Nm^3). The energy value of biogas varies between 4.5 and 8.5 kWh/m^3, depending on the relative amounts of methane, carbon dioxide and other gases present.

Both methane and carbon dioxide are odourless. If raw biogas smells, it is usually due to the presence of sulphur compounds. Biogas may ignite at concentrations of about 5-20 % in air, depending on the methane concentration. Methane is lighter than air, whereas carbon dioxide is heavier. This is considered to be advantageous from a safety point of view, since methane easily rises and is quickly diluted by the air.

BIOGAS AS A VEHICLE FUEL

Biogas has been used as a vehicle fuel in Sweden since the 1940's. At that time, it was collected mainly from anaerobically-treated manure and used to fuel vehicles constructed to run on "wood gas", a mixture of gases containing mainly carbon monoxide and hydrogen obtained through the incomplete combustion of charcoal. In more recent years, interest has grown in using biogas as a vehicle fuel, and Sweden is today (2004) a world leader in this development.

PRE-TREATMENT OF THE GAS

A fairly extensive pre-treatment procedure is needed for biogas intended for use as a vehicle fuel. Initially, the energy value must be increased by upgrading, that is removal of carbon dioxide. Furthermore, water and other constituents such as hydrogen sulphide, that are potentially corrosive or hazardous for human health or the environment, must be removed. Particles are also separated out to avoid mechanical damage. Finally, the gas is compressed (i.e. pressurized) before use. Producing vehicle fuel from biogas is thus relatively expensive, since it requires pre-treatment plants as well as infra-structure development, including gas-driven vehicles and filling stations. However, the environmental advantages of biogas, especially when it replaces petrol or diesel, mean that its use as a fuel is becoming increasingly important. A Swedish Government inquiry (SOU 1996:184) concluded that, in comparison with other fuels such as electricity, ethanol and rape methyl ester, biogas is the most environmentally-friendly vehicle fuel.

Refuse lorries can be run on the gaseous fuel produced from the waste they transport.

TECHNICIAL DESIGN OF BIOGAS-DRIVEN VEHICLES

The technical design of biogas-driven vehicles is exactly the same as for vehicles fuelled with natural gas. As a driver, you hardly notice any difference between methane or conventional fuel. Cars that run on methane are usually hybrids (bi-fuel), that is they have two separate tanks for petrol and gas respectively. The same motor may be used for both fuels, and it is easy to switch to petrol if the gas runs out. This is advantageous as the number of filling stations supplying methane is still limited. Most biogas-powered cars use petrol to start and then switch to gas after a few seconds. In contrast, heavy vehicles such as buses are constructed to use gas alone. The Otto engine, which is always used for gas-driven vehicles, has slightly different properties compared to a diesel engine. For example, the Otto cycle requires a somewhat heavier engine with a slightly higher fuel consumption.

The gas is stored in the vehicle in tanks at a pressure of about 200 bars. Biogas needs to be stored in fairly large tanks, since it has a relatively low density. However, these tanks are nowadays integrated in the vehicle in such a way that they do not take up valuable baggage space. The relatively short range provided by one full tank of gas (between 250 and 400 kilometres) means that heavy gas vehicles are best suited for short-distance driving, for example in urban areas.

The first Swedish gas-fuelled car, a Volvo 850 bi-fuel, was introduced in 1996. Today, several models are on the market. A gas vehicle costs about 10 – 20 % more than the equivalent standard model. However, the government is now introducing incentives such as subsidies and tax rebates to stimulate the use of several alternative fuels, including biogas.

Filling stations supplying vehicle gas are mostly situated in the south and west of Sweden, but gas pumps are now being installed at an increasing number of locations across the country.

Buses run on biogas are quieter, pollute the environment less, and are less smelly than diesel buses. In this picture, biogas-driven buses are being lined-up to fill up overnight.

Several makes of cars running on biogas are now on the market, like the Ford Transit shown here.

FILLING UP WITH GAS

Upgraded biogas intended for use as a vehicle fuel is distributed to the filling station in one of three ways: either directly via a pipeline from the biogas plant, or mixed with natural gas in the gas grid, or by a container system, in which containers filled with pressurized biogas are replaced with new ones as soon as the gas runs out. Filling up with gas is just as quick as filling up with petrol or diesel. Stations providing gas at a much slower rate are used for bus fleets. These are cheaper to run due to the lower compressor capacity. In this case, filling takes between 5 and 20 hours. Stations providing vehicle gas are most numerous in the far south and west of Sweden, although new stations are currently being built in many places across the country. The number of gas vehicles on the roads is increasing in line with the increasing number of gas-filling stations. An updated map of all filling stations providing vehicle gas can be downloaded from www.miljofordon.se.

FACTS
A CLEAN AND SAFE FUEL

Emissions of dust and particles into the environment from gas-fuelled vehicles are negligible. The exhaust is also free from pollutants such as benzene and toluene. The fumes smell less and the engine is quieter and vibrates less compared to a diesel engine. This reduces traffic noise, which is important for heavy vehicle traffic in urban areas.

Emissions of carbon monoxide, hydrocarbons, sulphur compounds and nitrogen oxides are lower than from petrol or diesel driven vehicles. Stricter regulations and improved engine technology and design are now also contributing to decreased emissions from petrol and diesel driven vehicles. However, one clear environmental advantage of biogas is that its combustion does not lead to the release of greenhouse gases into the atmosphere.

Methane is a safer fuel than petrol and diesel since it is non-toxic and lighter than air. In the event of a leak, biogas quickly rises and becomes diluted by clean air. The gas tank has a robust construction which gives it a larger tolerance to stresses than conventional petrol tanks.

A VERSATILE ENERGY GAS

Infrared-heat for greenhouses may be produced using methane as a fuel. Biogas may also be used to supply the plants with carbon dioxide.

Biogas is perfect for fuelling gas cookers. Professionals always cook over an open flame, since the temperature can be more exactly regulated than with electric cookers.

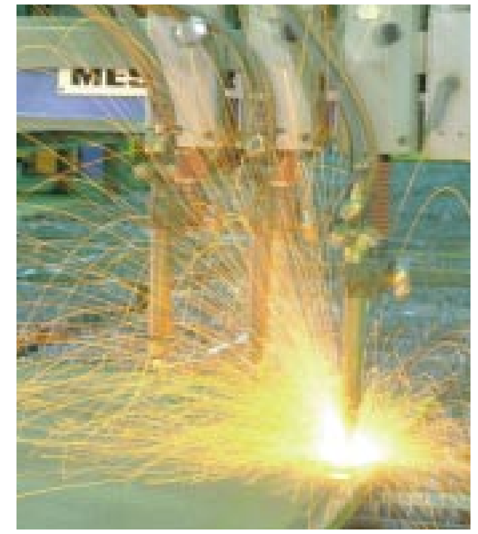
Methane is also suitable for infra-red heating of greenhouses or other localities that either have a large turnover of air or are only used occasionally, for example verandas and warehouses. The use of infra-red heat in such localities is cheap and efficient, because the infra-red heater only warms up "objects" such as people, plants and machines and not the air around them. In warm countries, such as China and India, there is little need for heat, and locally-produced biogas from small-scale farms and waste water treatment plants is mainly used for cooking and lighting.

Methane may be used to fuel gas lamps.

In this picture, methane is burning in a fake log fire.

New customers are reached when biogas is introduced into the gas grid.

Methane can be used to dry paper by infra-red radiation.



Biogas is one of the so-called 'energy gases', a group of high energy content gases utilised as fuels, that includes natural gas, liquefied petroleum gas, town gas and hydrogen gas. The use of energy gases is expected to increase in the future, due to several technical and environmental advantages compared to solid and liquid fuels.

The methane molecule (CH_4) found in biogas and natural gas is the simplest of all natural hydrocarbons. On combustion of methane, more water and less carbon dioxide is produced compared to more complex hydrocarbons such as coal, oil and solid fuels (e.g. wood and pellets), due to the high content of hydrogen relative to carbon. Furthermore, the carbon dioxide produced from the combustion of biogas does not contribute to the greenhouse effect, giving biogas an environmental advantage over natural gas, in which the hydrocarbons originate from fossil carbon.

METHANE - A GREENHOUSE GAS

Methane is in itself a potent greenhouse gas, which absorbs infrared light even more effectively than carbon dioxide. As methane is relatively persistent in the atmosphere, its 'greenhouse effect', calculated for a period of one hundred years, is more than 20 times stronger than that of carbon dioxide. However, due to the large amounts produced by human activity such as burning of fossil fuels, carbon dioxide is still the most important greenhouse gas, contributing more than 60 %. Methane is the next most important greenhouse gas, (contributing c. 20 % to the greenhouse effect), mostly due to increases in livestock populations, expansion in the area of rice production, and leakages during extraction of fossil fuels. It is therefore of utmost importance that emissions of methane are minimised during all handling steps, including production, distribution, and final use of the gas, in order to retain the environmental benefits of biogas.

THE GAS GRID OPENS UP NEW POSSIBILITIES

Just like natural gas, biogas can be distributed through the gas grid. Well developed gas grids were already in use during the 19^{th} century in many European cities, distributing town gas to fuel lamps and cookers. Town gas was originally produced through the gasification of coal, but it is today extracted from light petrol (naphta). The main constituents of town gas are hydrogen, methane and carbon dioxide, with small amounts of carbon monoxide and nitrogen gas. Functioning town gas grids still exist today, for example in Stockholm. However, the town gas has now been almost completely replaced by other energy gases, especially natural gas. Increasing the supply of biogas to the gas grid increases the amount of environmentally friendly gas, or "green gas", distributed to the final consumer. This is now (2004) being done in Gothenburg, Helsingborg and Laholm. Another example is Hammarby Sjöstad in Stockholm, where biogas produced from waste water is used to fuel biogas cookers in small apartments. This is made possible by the distribution of biogas through a separate gas grid.

Supplying biogas via the gas grid opens up many new markets. Just like natural gas, biogas can be used as a fuel in gas cookers, stoves/heaters and ovens, and to heat saunas and hot water boilers. The carbon dioxide produced by the combustion of methane can be used in greenhouses to promote plant growth.

INDUSTRIAL USE OF BIOGAS

Several industries, such as sugar refineries, distilleries and pulp mills generate waste water that may be digested anaerobically in an 'on-site' biogas process. This is advantageous since it is a cost-effective way of recycling waste into power and heat. Some examples of industrial uses of methane include heating of buildings, combined power and heat production, production of hot water and water vapour, heating of ovens etc. In pulp mills, biogas can be used to dry paper either directly through infra-red radiation or indirectly through the production of water vapour.

FACTS
ENERGY GASES

Natural gas consists of gaseous hydrocarbons that were formed between 50 and 400 million years ago by the anaerobic decomposition of organisms such as plants, algae and plankton. About 90 % of the gas is methane. It is pumped up, either together with oil, or from separate gas wells. Natural gas is the commonest energy gas, representing more than 20 % of the total world energy supply.

Gasol(ine), or Liquefied Petroleum Gas (LPG), consists of about 95 % propane (C_3H_8). It is produced through the separation of higher hydrocarbons from natural gas, or by refining raw oil. Gasol becomes liquefied when put under a slight pressure, and so can be easily stored and transported in liquid form. Gasol is utilised as a vehicle fuel in, for example, the Netherlands and Denmark, whereas in Sweden it is mostly used for industrial purposes.

Hydrogen (H_2) is formed naturally, for example during alcohol fermentation. However, it can also be artificially produced by fission of water or from natural gas. Water is the only product formed during hydrogen combustion. A lot of research is underway to develop techniques for the production, transport and storage of hydrogen, to enable a wider utilisation of hydrogen in the future, for example in fuel cells, which in principle function as batteries driven by hydrogen.

BIOGAS TREATMENT AND DISTRIBUTION

The gas in a digestion chamber is under a slight pressure and can be extracted without the help of a fan. Normally, the gas is then stored in a low pressure tank which acts as a buffer to even out differences in production and consumption rates of biogas. As already mentioned, the gas must then be refined and dried to some extent, depending on the ultimate use. Biogas must also be upgraded to obtain the same quality as natural gas, if it is intended for use as a vehicle fuel or if it is added to the gas grid.

UPGRADING

Biogas is upgraded by removing carbon dioxide. This increases the energy content which enables longer driving distances for a given volume of gas in the vehicle tank. The removal of carbon dioxide also ensures a constant gas quality, in terms of the calorific value, that is the energy released during complete combustion of one Nm^3 of gas. According to the vehicle-manufacturers, this is a prerequisite to minimise emissions of nitrogenous gases during combustion. Apart from removing carbon dioxide, commonly-used upgrading techniques also remove other potentially harmful substances that may be found in biogas. However, it is often advantageous to first remove some substances, such as particles and hydrogen sulphide, if they are present in large concentrations, since otherwise these may cause problems with corrosion and mechanical wear in the upgrading plant. Today, four different techniques are used at Swedish upgrading plants.

According to law, upgraded biogas must be 'odorised' with a scented additive to make leaks noticeable. A hydrocarbon, for example liquefied petroleum gas, must also be added before upgraded biogas can be introduced to the gas grid, since it still has a roughly 10 % lower energy value than natural gas. Biogas then has similar properties to natural gas, which means that it can also be used in the same way.

QUALITY SPECIFICATIONS

The Swedish quality specification for biogas intended for use as a vehicle fuel specifies two different fuel grades: type A for vehicles without lambda regulators (for example lorries) and type B for vehicles with lambda regulators (cars). Briefly, this classification means that private cars run on biogas with a methane content of at least 95 %, whilst heavier vehicles need at least 96 %. This standard was adopted to ensure a uniform quality of the gas originating from all upgrading plants and to enable gas vehicles to run on both biogas and natural gas.

Cylinders are used for storage of pressurised biogas to even out differences in production and use.

A plant where biogas is upgraded to a quality suitable for vehicles, here using the water-wash principle. Relatively advanced equipment is required.

Biogas is dried before being used as a vehicle fuel.

DISTRIBUTION

The commonest use of biogas is still as a local fuel. The pipelines leading the biogas to, in many cases, single users in the vicinity of the biogas plant, are made out of plastic since the pressure is kept low. Upgraded biogas may also be distributed to filling stations in a mobile container system. Now that biogas can be introduced to the general gas grid, its use is likely to increase dramatically. Since 1985, Sweden has been connected to the European gas grid through a pipeline that runs from Malmö in the south up to Stenungsund (2004). From this main pipeline, branches connect to regional and local networks. The highest pressure, c. 80 bars, is found in the main pipeline, whereas the pressure in the branches is lower than in an ordinary water pipe. Many biogas plants are situated along the natural gas network and can easily be connected to it.

Excerpts from the Swedish Standard for biogas as a vehicle fuel (SS 15 54 38)

Component	Units	Standard A	Standard B
Methane, CH_4	vol-%	96-98	95-99
Water content	mg/Nm^3	< 32	< 32
Oxygen, O_2	vol-%	< 1	< 1
Total sulphur	mg/Nm^3	< 23	< 23

RENEWABLE GAS IN THE GAS GRID

Production from a biogas plant does not always correspond to the local demand, which varies considerably during the year. Consequently, large amounts of biogas must be flared off each year. One way to increase the demand for biogas is by distributing it via the gas grid following the same principle applied to "green electricity". When filling your vehicle at a gas station, the amount of biogas is registered and discounted against the amount re-supplied to the system. Thus, biogas reaches new customers who are willing to pay for an increased proportion of renewable gas in the system.

FACTS

UPGRADING TECHNIQUES

Physical absorption (water wash) is the most commonly used method for upgrading biogas in Sweden. This method makes use of the fact that gases like carbon dioxide, hydrogen sulphide and ammonia are more readily dissolved in water than methane. The solubility of carbon dioxide increases with increasing pressure and decreasing temperature.

Pressure Swing Adsorption (PSA) is the second commonest method in use. PSA separates out carbon dioxide, oxygen, nitrogen and hydrogen sulphide, trapping molecules according to molecular size using, for example, activated carbon at different pressures. Hence, the method is sometimes called the 'molecular sieve' technique.

Absorption using Selexol is a method in which carbon dioxide, hydrogen sulphide and ammonia are absorbed by Selexol, a glycol solution. The method is based on the same principle as physical absorption with water. However, Selexol is more effective, since it absorbs three times more carbon dioxide.

Chemical absorption (chemisorption) uses a chemical to bind carbon dioxide. The advantage of this method is that the chemical only absorbs carbon dioxide and, if present, hydrogen sulphide, whereas virtually no methane is removed. This leads to a very high purity of the upgraded biogas, which contains about 99 % methane.

THE DIGESTED RESIDUE

The more organic material present in the raw material, the more biogas will be produced. However, it is unlikely that all of the organic matter initially present will be decomposed within a reasonable time. The remaining residue consists of this undigested organic material, as well as inorganic material such as metals and minerals, and newly-formed biomass (i.e. microorganisms that grew during the digestion process). This anaerobic residue is very nutrient-rich and will also provide soils with fresh biomass and humus. However, the residue cannot be used as a fertiliser if it contains disease-carrying or pathogenic organisms, heavy metals, hazardous organic compounds or pollutants visible to the naked eye, such as plastics. In general, contaminated raw material will result in a contaminated end-product. Thus, careful source-sorting is essential for a successful result.

A soil conditioner perfectly suited for parks and gardens is obtained by mixing anaerobic residue with dry organic material such as wood chips, bark and twigs.

DIFFERENT TYPES OF RESIDUES

The nature of the digested residue varies considerably depending on the raw material used. This, in turn, determines whether the residue is suitable as a fertiliser on arable land, or if it is better suited for combustion. Digestion residues from biogas plants may be classified into several different categories:

*Industrial waste water normally requires more treatment after an initial anaerobic digestion step. The composition of industrial waste water is quite variable, so it may sometimes need additional treatment in a municipal waste water plant.

*Sewage sludge from municipal treatment plants is normally dewatered after anaerobic digestion, to obtain a somewhat drier product, which takes up less space, both during storage and also in the case of landfill deposition. Sewage sludge usually has a high phosphorus content, which is valuable in terms of plant nutrition. However, very little sludge is used as fertiliser due to the relatively large content of heavy metals.

*Bio-manure is a product obtained from biogas plants treating relatively clean, unpolluted, materials such as manure, source-sorted organic waste, or agricultural crops. The bio-manure is intended for use on agricultural land and has a nutrient content and consistency similar to that of liquid manure, such as cow and pig slurry. The concentrations of pollutants are generally very low.

Equipment used for spreading liquid manure (slurry) is often also ideal for spreading biomanure.

Careful source-separation of the raw material is critically important.

*Soil conditioners are made out of relatively dry anaerobic residues that are mixed with topsoil, sand, wood chips, bark etc. Soil conditioners can include most kinds of anaerobically-digested organic residues, although some may require pre-treatment such as dewatering or composting (i.e. biological decomposition in contact with air). Products based on bio-manure may also be suitable as fertilisers on arable land, although the nutrient content may need to be optimised by using additives. Products based on more contaminated raw materials are more suitable for use in construction works or as a cover material in landfills.

*Landfill products usually remain permanently in the landfill in which they were initially deposited. However, with new techniques for deposition of the waste, the residue may in some cases be recovered and used as a soil conditioner or as construction material.

A PRODUCT RICH IN NITROGEN

In a biogas process, all the nutrients in the original organic material are preserved in the final product.

Some of the organically-bound nitrogen is released during digestion and converted to ammonium (NH_4^+). This is favourable, in that ammonium is water-soluble and therefore easily taken up by plants, whereas organic nitrogen must first be 'mineralised' by soil microbial activity. However, ammonium is also easily converted to ammonia gas (NH_3), especially at high pH values. Thus, care should be taken during handling of the residue, to ensure that nitrogen is not lost to the air as ammonia. Hence, the residue should be stored in closed tanks, which also minimises the risk of methane leakage to the atmosphere. Ammonia emissions can be minimised by incorporating the residue into the soil.

FACTS

CERTIFYING THE RESIDUE

A certification system for anaerobic residues and composts was initiated in Sweden in 1999 by the Swedish Association of Waste Management, together with several other interested parties and organisations. Under this system, organic products obtained from the biological treatment of organic waste are certified with respect to environmental effects and quality. This further develops the market for these products by increasing customer confidence.

The certification is voluntary and is based on the principle of transparency to the customer. This is achieved by careful documentation and control of various environmental- and quality aspects. To gain certification, the producer must pass an initial 'qualification' year, during which routines and procedures are checked and samples are taken on a regular basis. The producer receives support, advice and training during this period.

A certificate is issued once the requirements of the qualification year are fulfilled. The plant is then inspected once or twice a year to ensure that good practices are maintained. The inspection and certification services are undertaken by SP Swedish National Testing and Research Institute. The certification rules (SPCR 120) can be downloaded from their homepage, www.sp.se. A list of the biogas plants that are currently certified can also be found on this site.

MICROBIOLOGY OF THE BIOGAS PROCESS

Methane-producing microorganisms belong to the group Archaeans, which have very specific properties. They are found in many extreme environments, for example in hot springs.

Methane producers magnified one thousand times in the microscope. Two different kinds of acetate-utilising methane producers are illustrated; Methanosaeta that forms chains and Methanosarcina that grows in aggregates.

The anaerobic digestion of organic waste in a biogas process is virtually identical to the decomposition of feed that takes place in the rumen of cows. It is a complicated process in which several different groups of microorganisms take part. These microorganisms are all found in natural environments, such as manure, and are initially introduced to the digestion chamber together with the raw material. The degradation of the organic substrate is a stepwise process. Each step must be successfully completed for the process to proceed all the way through to the production of methane and carbon dioxide. In this respect, each group of microorganisms plays a specific role.

THE DIFFERENT DEGRADATION STEPS

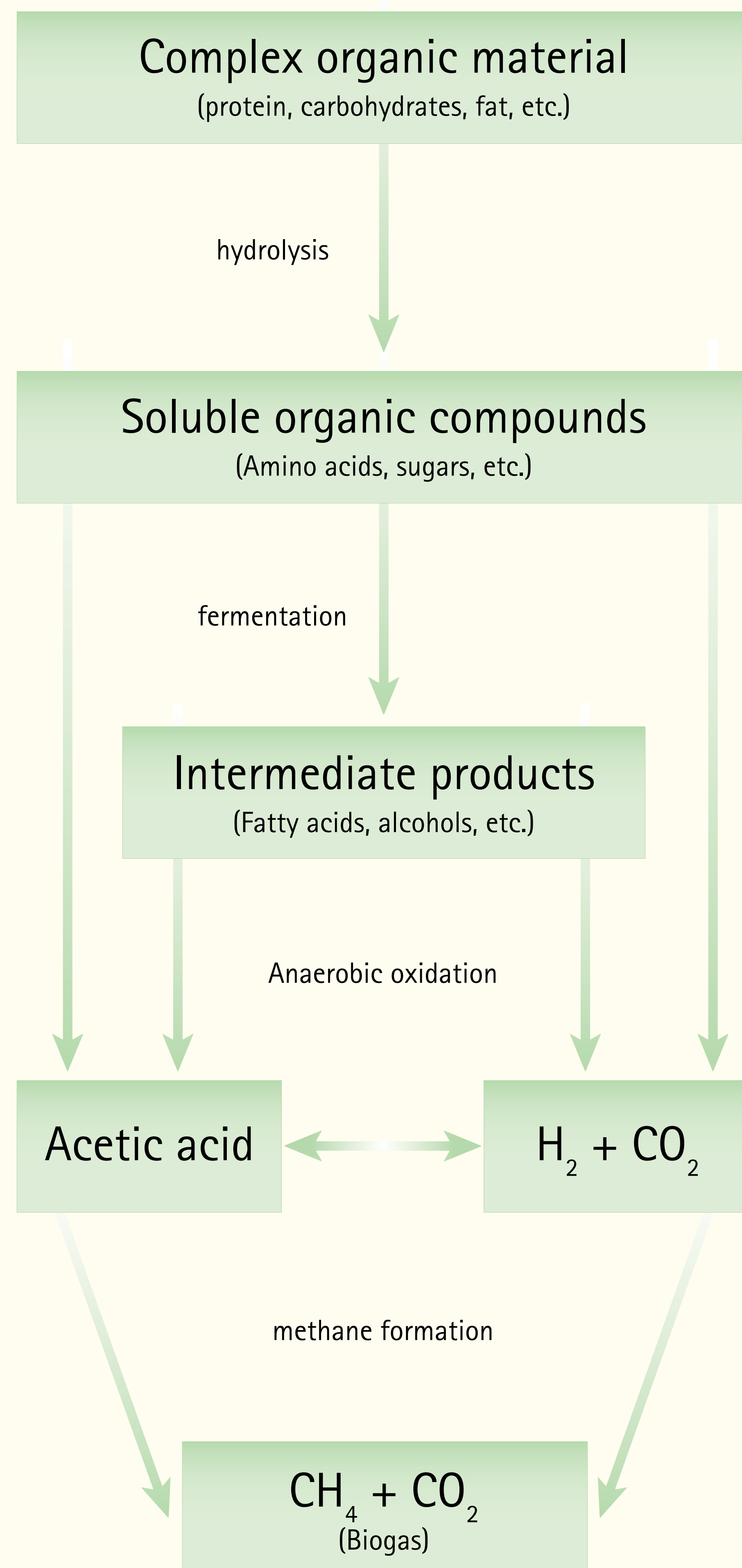
First of all, large molecules such as proteins, fats and carbohydrates are broken down into smaller ones with the help of enzymes secreted by hydrolytic bacteria. This step is called hydrolysis. The breakdown products are used by several kinds of bacteria that ferment them to so-called volatile fatty acids (VFA) in the process of fermentation. Acetic acid, butyric acid, propionic acid, valeric acid and capronic acid are examples of fatty acids formed in this step. Apart from these acids, hydrogen gas, carbon dioxide and some alcohols are also produced.

Of all the products formed during fermentation, only acetic acid, or hydrogen and carbon dioxide can be directly converted to methane. All the other fatty acids must first be further degraded by bacteria to acetic acid and hydrogen. This degradation step is called anaerobic oxidation and it can only proceed if the hydrogen pressure of the process is very low.

In the final degradation step, either acetic acid or hydrogen and carbon dioxide are converted into methane and carbon dioxide. These two pathways are carried out by two different types of methane-producing microorganisms, with very special properties. In fact, they are so special that they are not even classified as bacteria, but are now considered to belong to a separate group of microorganisms, the so-called Archaeans.

THE ROLE OF METHANE PRODUCERS

Methane producers that utilise hydrogen play a very important role in the biogas process since, apart from producing methane, they maintain a low hydrogen pressure, enabling the degradation of fatty acids by anaerobic oxidation. This cooperation between two groups of microorganisms, in this case methane-producers and acetic acid forming bacteria, is called syntrophy. If methane production is interrupted, the acids content quickly increases and the pH, which should normally lie between 7 and 8, decreases. This may eventually lead to a complete failure of the whole process. Methane-producers cannot tolerate even very low concentrations of oxygen, and are also sensitive to high concentrations of fatty acids and ammonia.



Schematic illustration of the anaerobic microbiological degradation of complex organic material to the final products, methane and carbon dioxide.

Furthermore, their growth is extremely slow and they have very specific nutrient and vitamin requirements. A successful biogas process requires optimal conditions for all the microorganisms involved, including the methane-producers, so that they degrade the substrate as completely as possible.

TEMPERATURE

Anaerobic microorganisms are active within a broad temperature range, from psychrophilic conditions (optimum 15–30 °C) via mesophilic (optimum 35–40 °C) to thermophilic conditions (optimum 55–65 °C). In general, the higher the temperature, the faster the process. Temperature also influences the rate and degree of degradation of different organic contaminants, which will in turn affect the composition of the residue. The optimal temperature for biogas processes varies, for example depending on the nature of the substrate. Usually, biogas processes are either mesophilic (37 °C) or thermophilic (55 °C).

During anaerobic digestion, the volume of the raw material is reduced, since most of the energy and carbon present in the substrate are conserved in the end-products methane and carbon dioxide, and only small amounts of heat and biomass are formed. In contrast, aerobic degradation processes, like composts, produce more heat and biomass. Indeed, they are self-heating, whereas an energy supply is almost always needed to keep the anaerobic process warm. A small amount of the produced biogas is usually used for this purpose.

FACTS

HYGIENE

The substrate can be pasteurised in tanks to reduce the number of pathogens.

Raw organic wastes almost always contain some disease-carrying (pathogenic) organisms, for example bacteria, viruses and parasites. This places great demands on system design and control in order to prevent the spread of disease.

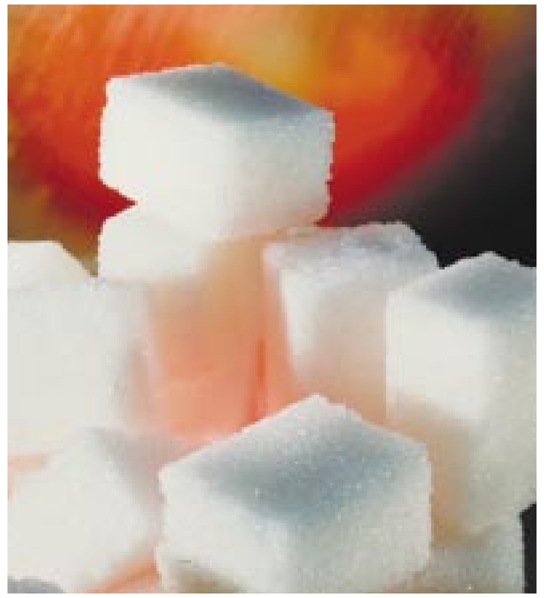
Several pathogenic organisms, such as Salmonella, are difficult to cultivate and enumerate in the laboratory. Instead, so-called indicator organisms are counted (e.g. common colon or digestive tract bacteria) in the material before and after anaerobic treatment. An increase in the number of indicator organisms is an indication of an increased number of pathogens.

One way to reduce the number of pathogens is to heat (pasteurise) the substrate at 70°C for one hour. The number of indicator organisms is then strongly reduced, and Salmonella and other pathogens are usually effectively killed by this treatment. However, spore-forming bacteria and certain heat-tolerant viruses can survive. According to EU-regulations, pasteurisation is obligatory in processing plants that treat animal by-products (e.g. from slaughterhouses).

It is very important to clean and disinfect all tank vehicles entering and leaving the biogas plant, in order to avoid re-infection of the final product. One way to maintain good sanitation is to have separate tanks in the vehicles for the transport of raw substrate and residues.

SUBSTRATES FOR BIOGAS

In arable farming systems without livestock, a "mechanical cow" can be created that supplies bio-manure from anaerobic digestion of ley crops.



Co-digesting process water from a sugar refinery with manure can increase the methane content and improve biogas quality.

Clover leys fix nitrogen from the air. This is returned to the soil in the bio-manure produced when the crop is digested in a biogas process.

The substrates used for biogas production may have quite varying properties, for example with respect to water content. Municipal and industrial waste waters have dry matter contents, that is the "water free part", of less than 5 %, whereas sludges from waste water treatment plants, manure slurries and liquid waste mixtures have dry matter contents between 5 and 15 %. Kitchen wastes and plant materials are comprised primarily of solids, so the dry matter content is above 20-25 %. The composition of biogas varies considerably depending on the material digested, although the choice of process technique, temperature, and the system used to collect the gas also play a role.

CO-DIGESTION PRODUCES MORE METHANE

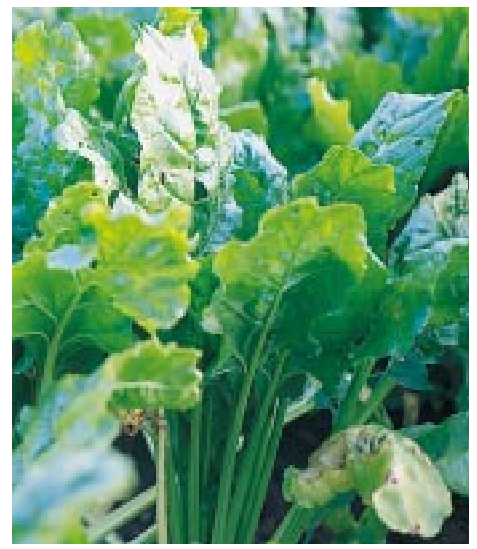
Biogas produced from waste water, agricultural crops, or manure is sometimes called digestion gas, whereas the gas extracted from landfills is called landfill gas. Digestion gas normally has a higher methane content, partly because it is produced under controlled conditions and partly because air is added to landfill gas when it is extracted with the help of fans. In addition, we can also distinguish between digestion gas produced from only sewage sludge and that produced from anaerobic co-digestion, that is from a mixture of several substrates such as source-separated kitchen waste or slaughterhouse waste, together with manure or sewage sludge. This usually results in higher methane and hydrogen sulphide contents compared to the digestion of municipal sewage sludge alone.

Composition of biogas (modified from Hagen et al. 2001)

Component	Units	Co-digestion	Sewage plant	Landfill
Methane	vol-%	60-75	55-65	45-55
Carbon dioxide	vol-%	25-40	35-45	30-40
Nitrogen gas	vol-%	< 1	< 1	5-15
Hydrogen sulphide	ppm	10-2000	10-40	50-300

Landfill gas is collected using pipes installed in the waste. The gas is often used to heat buildings in the vicinity of the landfill.

Sugar beet tops can be digested in a biogas process. The biogas produced can be a useful contribution to regional energy supplies.



COLLECTION OF LANDFILL GAS

Landfill gas is usually extracted from vertical, perforated gas pipes (or 'gas wells') that are drilled or pushed into the waste. Gas pipes inserted horizontally are also sometimes used. The yield of gas can be increased by recirculating the landfill leachate, so that organic material in the leachate can be converted to biogas. Traditional landfill gas extraction is a slow process that can easily take 50 years or more with mixed waste. In contrast, the process should be completed within five years in a well-functioning biocell where the anaerobic digestion is optimised with respect to temperature and moisture etc. The commonest use of landfill gas is to heat buildings in the vicinity of the plant. Even if there is no use for the biogas produced, it is still collected and flared off. This is done partly because methane is a potent greenhouse gas, but also because there is a risk of explosion if methane accumulates in the landfill. Burning the gas also reduces odours.

DIGESTION OF AGRICULTURAL CROPS

There is a growing interest in many countries in new developments in biogas technology that might further increase its importance as a source of energy. Environmental concerns and energy self-sufficiency are two important factors in this context. It seems likely that future increases in biogas production will rely on cultivated crops as the dominant substrate.

Smaller soil organic matter contents are often found on farms without grass leys and livestock, where the rotation has been dominated for many years by cereal crops. This can lead to a deterioration of soil structure and decreased crop yields. One way to avoid such problems would be to use part of the harvest as a substrate in a biogas process, and via the bio-manure, return nutrients and humus back to the soil. The biogas process then becomes a "mechanical cow", which also produces energy-rich methane gas that can be utilised on the farm. Crops like clover and lucerne leys or peas can fix considerable quantities of nitrogen from the air. If these crops are anaerobically digested, the nitrogen is retained in the residue, which can subsequently be used to fertilise the soil with relatively good precision.

FACTS

SUBSTRATE COMPOSITION

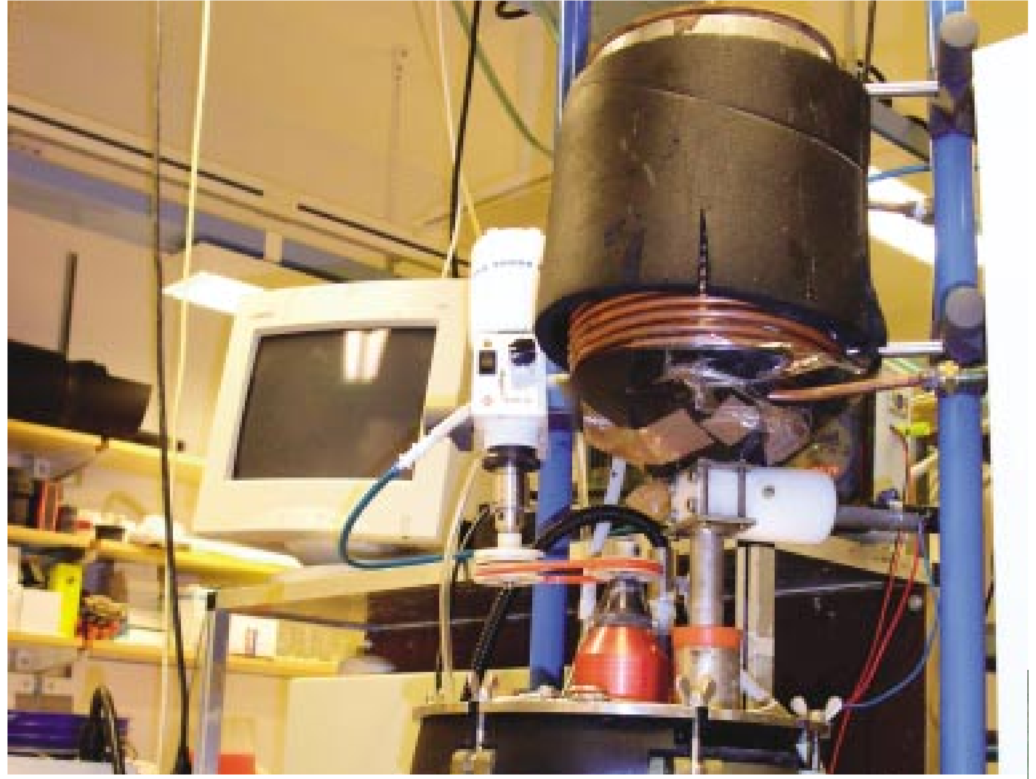
Organic material consists mostly of fat, protein and carbohydrate. Anaerobic decomposition of pure fat produces larger quantities of biogas than both protein and carbohydrate. In theory, both pure protein and fat produce biogas consisting of about 70 % methane and 30 % carbon dioxide, whilst biogas obtained from pure carbohydrate has equal proportions of these gases.

Calculations that account for both the amount and composition of biogas suggest that 0.85 Nm^3 of methane would be produced from 1 kg of fat, while the corresponding figures for protein and carbohydrate are 0.5 and 0.4 Nm^3 per kilogram.

Thus, in theory, meat and fish waste rich in fat and protein produce more methane per kg of waste than materials such as manure and sewage sludge. However, wastes high in protein also produce large quantities of hydrogen sulphide, which is both corrosive and poisonous.

Even if, in theory, large amounts of methane are obtained from fat-rich substrates, anaerobic digestion of such materials is not advisable in practice, since this sometimes causes problems for the microorganisms. In general, the microorganisms in a biogas process are sensitive and thrive best on a mixed diet of uniform quality served in appropriate portions. Technical problems can easily arise if these conditions are not met.

Digestion chambers at a sewage plant. Heated tanks, that contain several thousands cubic metres of sewage, are concealed under the tiles.



Small reactors can be studied in the laboratory, for example to try out a new substrate or optimise a process.

PROCESS DESIGN

In anaerobic filters, carrier materials of different sizes are added, to which the microorganisms can adhere. This retains them in the reactor and allows them to grow.

Anaerobic digestion technologies allow the optimisation of the process to achieve the desired result. The properties of the raw material, for example with respect to water content and consistence, determine the design of the biogas process, and in some cases, pre-treatment may be required. For example, solid substrates may need to be ground down and diluted with water so that they can be more easily pumped into the digestion chamber or 'reactor', as the gas-tight tank is sometimes called.

The choice of technique also depends on the main purpose of the treatment, which could either be to maximize the extraction of biogas, to stabilise large quantities of substrate or to decompose as much organic material as possible. Thermophilic processes are generally more effective than mesophilic. However, they are also more sensitive to disturbances. Mesophilic processes currently dominate, although thermophilic processes are becoming more common as knowledge improves on the best way to manage them. Biogas processes may be classified into batch or continuous processes. There is also a division between one-step and two-step processes. In addition, reactor designs may vary.

TYPES OF PROCESS

*Batch processes are those in which the raw material is added at the start of the digestion process with no further addition or removal of material. The material can be mixed to a greater or lesser extent. Batch processes are often used for the treatment of solid material, for example in landfills.

*Continuous processes are supplied with new material during the process either as a continuous flow or in smaller amounts during short feeding intervals (semi-continuously). This technique is often applied to substrates that can be pumped, and is the technique used for digestion of sludge at sewage treatment plants. The extent of mixing can vary, but 'total mixing' using rotating mixers is commonest.

*One-phase process: this is the technique used most frequently, where all degradation steps take place in one vessel, often accompanied by some degree of mixing.

*Two-phase process: the process is divided into a first stage of acid formation followed by a second step when methane is produced. This enables separate optimisation of the two steps, normally using two different digestion chambers. Biogas is formed in both stages, although most will be produced in the second phase. The method is particularly suitable for wet wastes from the food industry. In a two-phase process, the acid-rich leachate produced in the first step is fed to the methane-producing step at given time intervals.

COMMON TECHNIQUES FOR BIOGAS REACTORS

*Continuously stirred tank reactor (CSTR): the substrate is completely mixed with the help of various kinds of mixers or propellers. This technique is commonly used for one-phase processes treating sludge, kitchen waste and manure.

*Anaerobic filters (AF) are suitable for waste waters or sludges of low dry matter content. They use 'carrier' materials, often made out of plastic, to which the active microorganisms adhere. This is especially important for methane producers, which may otherwise be washed out due to their very slow growth rate. Biogas formed in an anaerobic filter optimised for methane production may have a very high quality, with a methane content of up to 85 %.

*Fluidised/Expanded beds (FB/EB) are also used for substrates of low dry matter contents. Small particles are added to which the microorganisms adhere. A strong upflow is created which suspends the particles so that the microorganisms come in contact with the substrate.

*Upflow anaerobic sludge blanket (UASB) allows the microorganisms to grow in aggregates. Thus, they remain in the reactor despite a strong inflow of substrate. New material is pumped in with sufficient power to mix the material, creating contact between the microorganisms and the substrate.

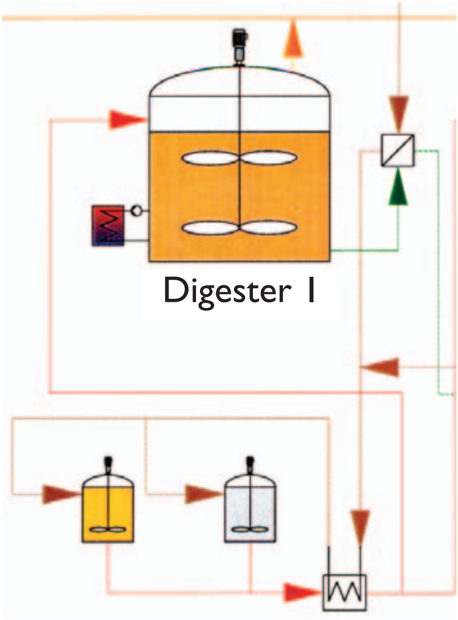
INSTRUCTIONS FOR THE OPERATION OF BIOGAS PLANTS

The Swedish Gas Association (SGF) has prepared general instructions for the operation of biogas plants, "Biogasanvisningar BGA 99". This provides a good overview of aspects of design, safety equipment, testing, control etc, and may be downloaded from SGF's homepage, www.gasforeningen.se.

Solid substrates, like ley crop silage, have relatively high dry matter contents and may need dilution or addition of a slurry like liquid manure or sewage sludge before being treated in a mixed biogas process.

FACTS

PROCESS PARAMETERS



Charging, or in more everyday language, "feeding" of the reactor, refers to the supply of raw material to the biogas process at certain times. A constant volume is maintained in continuous processes by removing digested material from the reactor at the same time as the new substrate is added.

Load is generally quoted as the organic loading rate (OLR). The organic loading rate, for example 2 kg organic substance per m^3 digestion vessel per day, represents the amount of organic material added to the process per unit time.

Hydraulic retention time (HRT) is defined as the average duration of the treatment for the material in the digester. It normally lies in the range between 12 and 25 days. 'Exposure time' is the interval between two charges, that is, the length of time the material is exposed to a certain temperature before new material is added.

Degradation efficiency, given in percent, is calculated as the proportion of the raw organic material that is converted to biogas during a specified time period. This can be used to estimate how long a certain material should be digested for optimal efficiency.

Gas yield expresses the amount of biogas in Nm^3 that is produced per weight of organic substrate added to the process.

FUTURE POTENTIAL

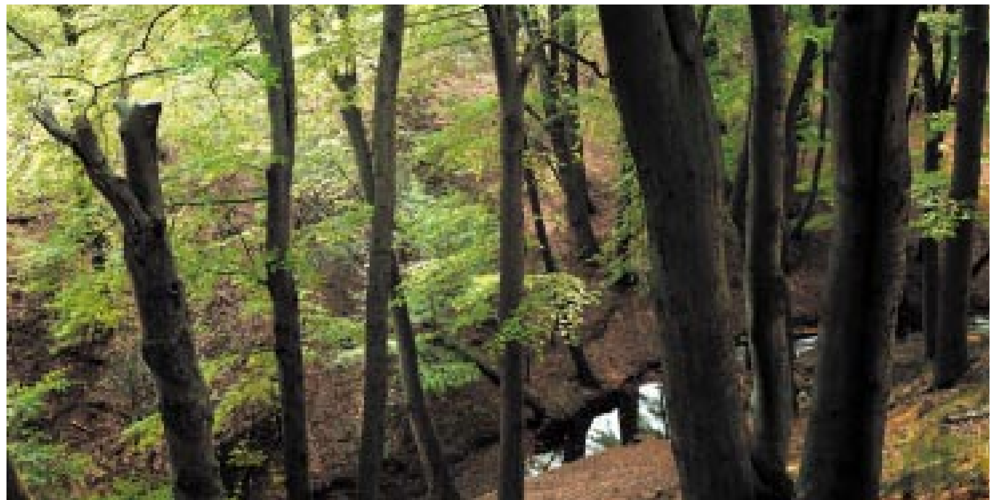
The potential for biogas production in Sweden has been calculated at 17 TWh ($17 \cdot 10^{12}$ Wh) per year, with approximately 80 % originating from agricultural by-products. In comparison, the total energy use in Sweden is about 400 TWh per year. If it was fully utilised, the total potential for biogas would be nearly equivalent to the total consumption of diesel in Sweden today, or about 20 % of the total fuel demand for private cars.

However, the full potential for biogas production is a long way from being realized. About 1.5 TWh per year is produced in Sweden (2003), at roughly 140 waste water treatment plants, 60 landfills and ten or so larger biogas plants. An expansion of biogas production would help to meet several of the environmental quality objectives adopted by the Swedish government, including 'minimizing the influence of human activities on climate', 'clean air', 'only natural acidification' and "good urban environments". The Swedish Parliament has also set the target that by 2010, at least 35 % of kitchen waste from households, shops and restaurants should be recycled after biological treatment. The biogas process can also play an important role in helping to fulfil the EU fuel directive, which states that biofuels should represent 2 % of the total petrol and diesel sold in 2005, and 5.75 % by 2010. In addition, the knowledge and skills now being developed concerning the utilisation of biogas will be very valuable in the future development of new technologies and infrastructure related to the use of hydrogen gas as an energy source.

INTERNATIONAL OUTLOOK

The biogas process is well established in many countries, where it is mainly used at waste water treatment plants. In response to environmental pollution and climate change, measures are now being taken globally to decrease the use of fossil fuels. Not least in this context, self-sufficiency in energy will become increasingly important. An increased use of biogas as a fuel can play an important part in reducing our dependence on oil, and also help to dampen the 'greenhouse effect'. There is a growing interest in Europe in small-scale biogas production, especially for on-farm digestion of manure. One country making significant investments in this technology is Germany, but Austria, Denmark and Great Britain are also developing new plants. Apart from heat production, the generation of electricity is an important market for the biogas produced, and several European countries have, just like Sweden, introduced subsidies for distributors of "green electricity".

Sweden is a leading country in biogas technology and several Swedish companies have delivered complete treatment plants for the digestion, upgrading and distribution of biogas. In addition, Sweden is, together with Switzerland, pioneering the use of biogas as a vehicle fuel. This opens up new possibilities for exporting know-how and technology in the biogas area.



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Swedish Biogas Association, www.sbgf.org

Swedish Energy Agency, www.stem.se

Swedish Environmental Protection Agency, www.naturvardsverket.se

Swedish Gas Association, www.gasforeningen.se

Swedish Gas Centre, www.sgc.se

Swedish Institute of Agricultural and Environmental Engineering, www.jti.slu.se

Swedish Society for Nature Conservation, www.snf.se

THE SWEDISH BIOGAS ASSOCIATION

The Swedish Biogas Association (SBGF), which was founded in 1987, is a non-profit making society working to increase the production and use of biogas in Sweden. The members of the society include companies that own and run biogas plants, universities, consultants and other individuals with an interest in biogas, such as farmers and researchers.

The society´s activities include the dissemination of information through a homepage and by the publication of a journal "Nytt om Biogas" ('News on Biogas') that contains articles, press clippings and other relevant information on biogas related activities in Sweden and abroad. In addition, the association arranges seminars and participates at trade fairs to disseminate information on the biogas technique. The office of the Swedish Biogas Association will provide further information on the association itself and on membership, publications etc.

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