Chapter 7 Biogas

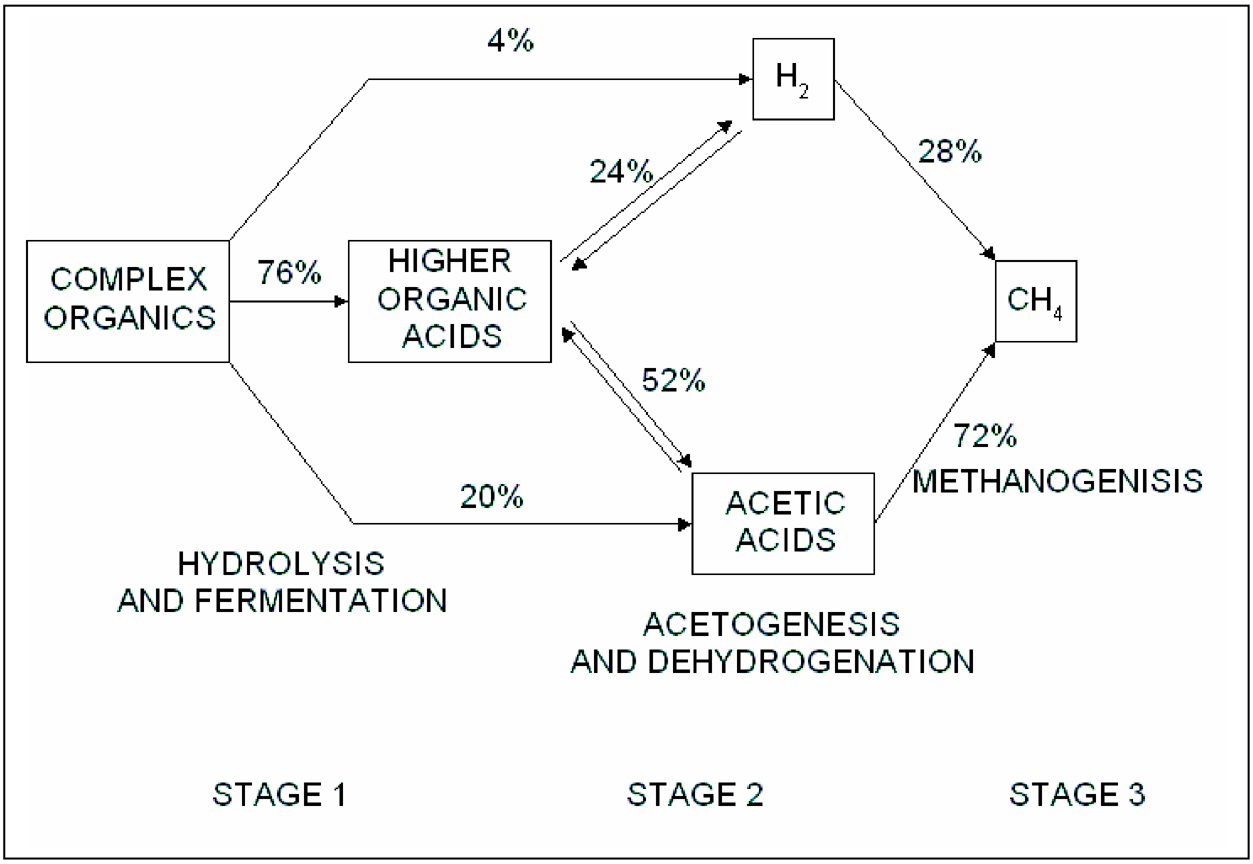
Biogas is produced from fermentation/digestion of the dry matter in biomass. The main ingredients in biogas are:

Methane (CH4)	Carbon dioxide (CO2)	Hydrogen Sulfide (H2S)	Hydrogen (H2)
55-75%	25-45%	0.1-1.0%	0-2 %

The composition of the gas depends very much on the biomass being digested.

Since the 1970's and until today advances in R&D in the biogas area have been rapid.

Anaerobic digestion is a complex process, which in its simplest form can be presented as a 3-stage process:



1. Organic polymers are broken down by enzymatic hydrolysis to monomers by bacteria
2. Monomers are fermented to various intermediates preliminary acetate, propionate and butyrate. Acetate is also produced by another group of microorganisms called acetogenic bacteria.
3. Anaerobic methanogenic bacteria break down acetic acids to methane and carbon dioxide.

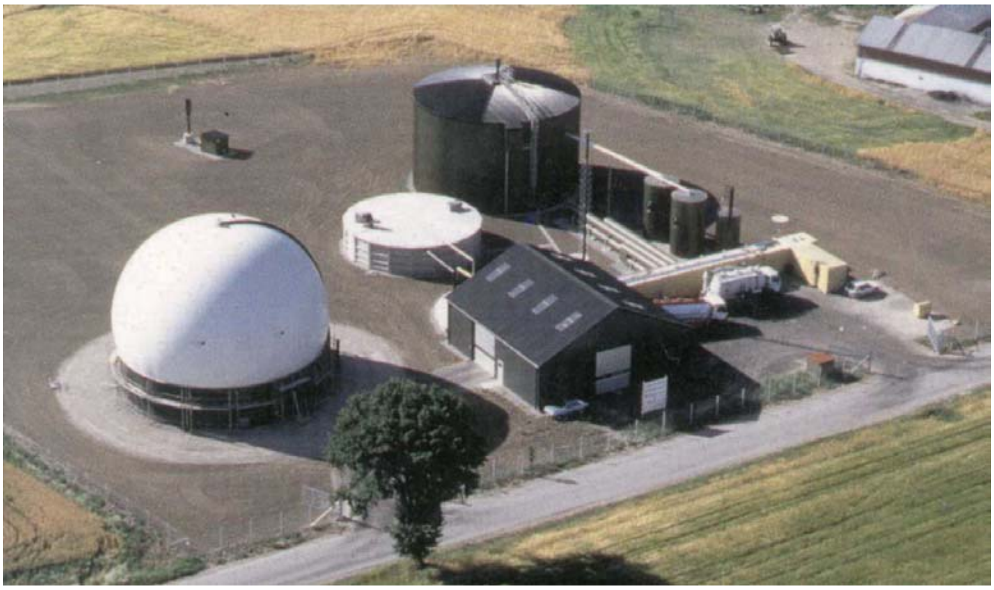
Microorganisms cause the digestion of biomass. If the microorganisms are having ideal living conditions, the population will grow and the digestion will increase. There are different ways of providing ideal living conditions for the microorganisms. Ways to improve the living conditions for the microorganisms are:

- Setting up a two-phase digestion
- Constantly stirring the tanks and by
- Maintaining a constant temperature in the tank.

A Danish co-operatively owned biogas plant

In Denmark it has been common that more farmers form a cooperative company who will own and operate a biogas plant. These companies can achieve municipal guaranties for cheap low interest loans, as well as they can receive public grants to reduce the size of loans to be obtained.

The turn over for the biogas plant is on sale of biogas for cogeneration, payment for treatment of industrial waste and selling of fertilizer. The farmers in the cooperative will further have the benefit of reduced storage costs for manure and increased fertilizer value of the manure. A well-managed and operated biogas plant is saving up money for future improvements and re investments in the plant.



Danish cooperatively owned biogas plant for digestion of animal manure and industrial waste

In geographical areas with a cold climate, where it is necessary to have the digester tanks insulated and heated to maintain the digestion during wintertime, it is common to have a stirred tank and a thermophilic process. Surplus heat from the biogas fired electricity production is used for heating of the digester tanks. This gives a higher gas yield each m^3 of digester tank and a reduced retention time in the digester tank; increased turn over on the installed equipment.

To have an increased turnover it is common that biogas plants are paid to treat waste from food processing industries. This waste is normally kept in separate tanks and used to boost the gas production whenever convenient for increased electricity production during electrical peak load.

Manure from the different farms is collected from smaller tank systems located at the farms, and supplied to a feeding tank located at the biogas plant. Each farmer also has tank capacity for storage of digested manure. The digested manure is used as fertilizer on the farmland belonging to the farm.

Supply of animal manure to the biogas plant

Digester tank and heat exchangers for Pasteurisation

The manure supplied to the biogas plant is pumped to the digester tank at certain time intervals (batch feeding). On some biogas plants the manure is given a heat treatment before it is fed to the digester tank. The heat treatment (Pasteurization at 67°C) is made to avoid diseases from one farm to spread to the other farms via the manure returned to the farms as fertilizer.

Based on experience with the industrial waste, this waste is injected some time before an increased gas production is wanted.

Road tanker for transportation of animal manure in Denmark

The road tanker, used for collection of "fresh" manure and supply of digested manure, is equipped with a computer system and weighing cells between the truck and the tanks. The driver gives the computer information about the farmer where manure is collected/fertilizer supplied, weighing cells are automatically registering the amount in the tanks, as well as date and time are automatically registered.

To minimize the risk for spreading of diseases between the different farms the collection of "fresh" manure and the supply of fertilizer is organized in a special way. The driver starts supplying fertilizer from the biogas plant to a farm and he brings back "fresh" manure from the same farm; when the tank for "fresh" manure has been emptied and the tank for fertilizer has been filled the road tanker is having a throughout cleaning at the biogas plant.

Biogas Plants in Thailand

In tropical areas the mesophilic process, which is less temperature sensitive then the thermophilic process, is the most common. The optimal temperature for the mesophilic process is 37°C; lower temperatures will slowly reduce the biological activity.

To reduce investment costs as well as operation costs biogas plants in Thailand are made in a more simple way than seen on the Danish example.

The simplest solution for a biogas plant is the cover lagoon system:

Covered waste water pond at a pig farm in the Chonburi Province

Gas collection from the cover lagoon

Biogas operated gas engines produce electricity from the gas produced in the cover lagoon in Chonburi

Generator switchboard for electricity supply from the gas engines

The efficiency of the cover lagoon system depends very much on the retention time (percentage of daily input of biomass related to total pond volume), but with normally used design criteria the efficiency can be expected around 60%. An industry with a Biological Oxygen Demand (BOD) in the wastewater around 14 000 mg/l, can after treatment in a cover lagoon in the outlet from the pond have a BOD around 5 600 mg/l. The BOD reduction will generate 0.8 m3 of biogas each kg of BOD removal. Adding water with low BOD from the end of the anaerobic process ponds will dilute the high inlet BOD and improve the biogas process.

Another system commonly used in Thailand is the ***channel digester combined with an Up flow Anaerobic Sludge Blanket (UASB), sand bed filter and after treatment ponds***. The outlet from the channel digester goes to the UASB for further treatment.

Channel digester, UASB and strainer at a pig farm in Ratchaburi

Close up of the top of the UASB and the gas outlet pipe

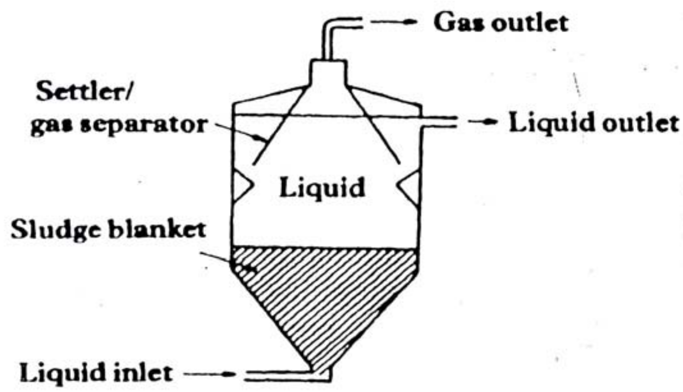
The efficiency of the channel digester is around 68% also depending on the retention time and the organic load and the efficiency of the UASB is around 60%. The total efficiency is around 87%.

After the UASB the wastewater goes to a sand bed filter where sludge is collected and sold as fertilizer, after the sand bed where sludge is collected. From the sand bed the wastewater flows to after treatment ponds.

Inlet to the sand bed filter at the pig farm at Ratchaburi

After treatment ponds/wet land

At the outlet from the after-treatment ponds the BOD has been reduced to 20 mg each liter of wastewater, this gives a total efficiency for the manure treatment in the channel digester, the UASB and the after-treatment ponds around 96%.



Upflow anaerobic sludge blanket digester

Advantages using UASB:

- High organic removal capacity
- Short HRT
- Low energy demand
- No need of packing media
- Proven technology

Disadvantages using UASB

- Difficult to control granulation process
- Granulation depends on wastewater properties
- Start-up eventually granular sludge
- Sensitive to organic and hydraulic shock loads
- Restricted to nearly solid free wastewater
- Ca^{2+} and NH_4^+ granular formation
- Re-start can result in granular flotation

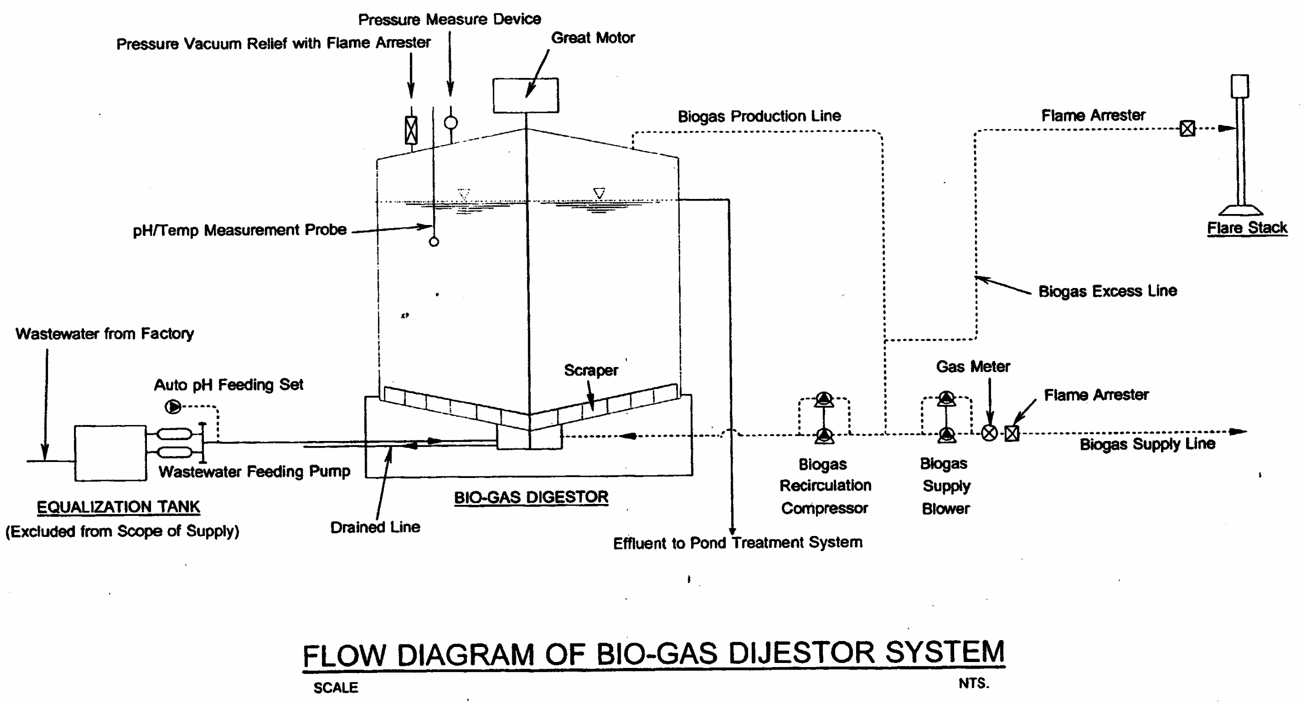
A further developed UASB system called H-UASB (High suspension - Up flow Anaerobic Sludge Blanket) in Ratchaburi

Another efficient system is the ***Closed Anaerobic Digester Tank***:

Closed digester tank at an Oil Palm Mill in Krabi

Alternative anaerobic treatment pond at an Oil Palm Mill, where no biogas is collected (Krabi)

When correctly dimensioned the closed anaerobic tank system can have BOD removal efficiency up to 95%. The closed anaerobic tank system is to some extent similar to the digester tank on the Danish biogas plant.



Inlet to the first anaerobic treatment pond from oil extraction at an Oil Palm Mill in Chumporn

Pump arrangement for pumping of wastewater from pond 1 to pond 2

The costs for treatment of wastewater and production of gas in the different systems used in Thailand are varying a great deal.

If a traditional water treatment pond system is to be equipped with a closed anaerobic tank system including gas engines for electricity production on the produced biogas the investment costs would amount approximately 10,000 Baht each m^3 wastewater to be handled every day: A plant size with daily capacity at 200 m^3/day will cost around 20 million Baht. The simple pay back time for this system, when calculating saved electricity as an income, will be about 4.3 years. The efficiency as wastewater treatment plant will be 95%. If setting up a new Oil Pal Mill there are further savings in reduced volume of the after treatment ponds and the need for land for the ponds.

The cheapest solution is the cover lagoon system; a system, including gas engines for electricity production on the produced biogas, will have investment costs around 5,000 Baht each m^3 of wastewater to be handled every day: A plant size with daily capacity at 200 m^3/day will cost around 10 million Baht. The simple pay back time for this system, when calculating saved electricity as an income, will be about 2.5 years. The efficiency as wastewater treatment will be 60%.