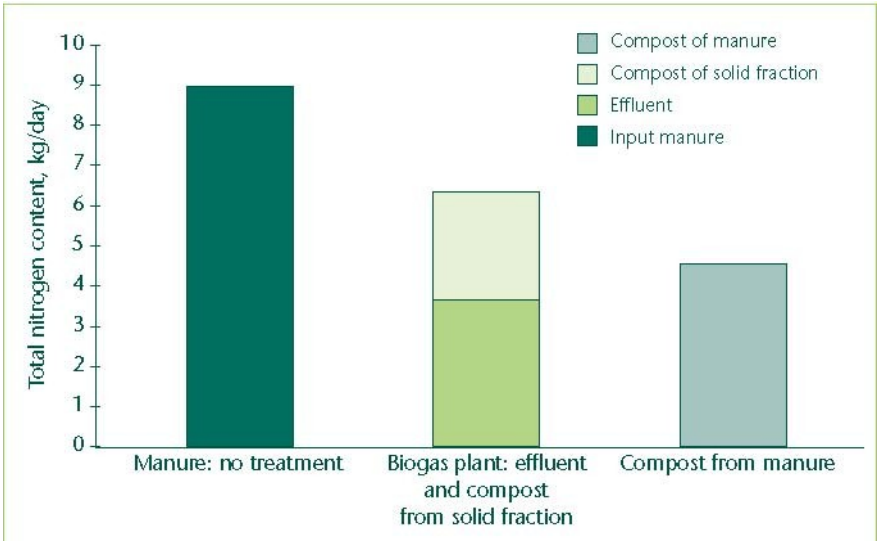
Solid compost from biogas plant digestion residues

On-farm biogas plants mainly digest manure slurry and the digestion residue is a liquid fertiliser. The dry matter content of the solid fraction is higher compared to manure and the composting process performs faster. The structure of the solid fraction compost looks different compared to the manure compost and the solid fraction compost smells better. The relative nitrogen content of input manure and output solid fraction is about the same. However, the total nitrogen content of the compost of the solid fraction is higher than of the compost from manure. The anaerobic treatment converts most of the nitrogen into ammonium in the effluent.

The results show, that the biogas plant is a suitable tool not only for renewable energy production but also for designing organic fertilisers by varying anaerobic process parameters like load rate of the reactor, retention time and mechanical treatment before, within and after the anaerobic process. The total nitrogen in kg/day before and after treatment:



Total nitrogen content expected before and after anaerobic and aerobic treatment. The daily added organic material is 1000 kg manure, a mixture of faeces from 25 dairy cows, straw and oat husks.

CARBON-NITROGEN RATIO

The bacteria responsible for the anaerobic process require both elements, as do all living organisms, but they consume carbon roughly 30 times faster than nitrogen. Assuming all other conditions are favourable for biogas production, a carbon – nitrogen ratio of about 30 – 1 is ideal for the raw material fed into a biogas plant. A higher ratio will leave carbon still available after the nitrogen has been consumed, starving some of the bacteria of this element. These will in turn die, returning nitrogen to the mixture, but slowing the process. Too much nitrogen will cause this to be left over at the end of digestion (which stops when the carbon has been consumed) and reduce the quality of the fertiliser produced by the biogas plant. The correct ratio of carbon to nitrogen will prevent loss of either fertiliser quality or methane content.

CARBON / NITROGEN RATIOS at HUNGARIAN BIOMASS SUPPLY		
Material	%N	C/N Ratio
Activated Sludge	5-6	6
Amaranth	3.6	11
Apple Pomace	1.1	13
Cabbage	3.6	12
Cardboard	0.10	400-563
Cow Manure	2.4	19
Corn Cobs	0.6	56-123
Corn Stalks	0.6-0.8	60-73
Farmyard Manure	2.25	14
Fruit	1.4	40
Garbage (Raw)	2.15	15-25
Grass Clippings	2.4	12-19
Hardwood Bark	0.241	223
Hardwoods (Avg.)	0.09	560
Hay (General)	2.10	15
Hay (legume)	2.5	16

ANIMAL BIOMASS PRODUCTION FOR HUNGARIAN FARMING CONDITIONS

Animal	Beef cow	Broiler	Dairy cow	Duck	Horse	Layer hen	Pig	Sheep	Turkey
Daily manure prod. (kg)	29	0,19	43	0,33	20,4	0,13	5,88	2,4	0,38
Total Solids (%)	14,7	26,3	14,0	27,3	29,4	23,1	13,1	27,5	26,3
Volatile Solids (%)	12,4	21,0	11,6	18,2	19,6	15,4	10,2	22,9	18,4

TEMPERATURE

Anaerobic breakdown of waste occurs at temperatures lying between 0°C and 69°C, but the action of the digesting bacteria will decrease sharply below 16°C. Production of gas is most rapid between 29°C and 41°C or between 49°C and 60°C. This is due to the fact that two different types of bacteria multiply best in these two different ranges, but the high temperature bacteria are much more sensitive to ambient influences. A temperature between 32°C and 35°C has proven most efficient for stable and continuous production of methane. Biogas produced outside this range will have a higher percentage of carbon dioxide and other gases than within this range.

PERCENTAGE OF SOLIDS

Anaerobic digestion of organics will proceed best if the input material consists of roughly 8 % solids. In the case of fresh cow manure, this is the equivalent of dilution with roughly an equal quantity of water.

BASIC DESIGN

The central part of an anaerobic plant is an enclosed tank known as the digester. This is an airtight tank filled with the organic waste, and which can be emptied of digested slurry with some means of catching the produced gas. Design differences mainly depend on the type of organic waste to be used as raw material, the temperatures to be used in digestion and the materials available for construction. Systems intended for the digestion of liquid or suspended solid waste (cow manure is a typical example of this variety) are mostly filled or emptied using pumps and pipe work. A simpler version is simply to gravity feed the tank and allow the digested slurry to overflow the tank. This has the advantage of being able to consume more solid matter as well, such as chopped vegetable waste, which would block a pump very quickly. This provides extra carbon to the system and raises the efficiency. Cow manure is very nitrogen rich and is improved by the addition of vegetable matter.

CONTINUOUS FEEDING (MOSTLY LIQUIDS)

The complete anaerobic digestion of cow manure takes about 8 weeks at normally warm temperatures. One third of the total biogas will be produced in the first week, another quarter in the second week and the remainder of the biogas production will be spread over the remaining 6 weeks. Gas production can be accelerated and made more consistent by continuously feeding the digester with small amounts of waste daily. This will also preserve the nitrogen level in the slurry for use as fertiliser. If such as continuous feeding system is used, then it is essential to ensure that the digester is large enough to contain all the material that will be fed through in a whole digestion cycle. One solution is to use a double digester, consuming the waste in two stages, with the main part of the biogas (methane) being produced in the first stage and the second stage finishing the digestion at a slower rate, but still producing another 20 % or so of the total biogas.

BATCH FEEDING (MOSTLY SOLIDS)

There are biogas systems designed to digest solid vegetable waste alone. Since plant solids will not flow through pipes, this type of digester is best used as a single batch digester. The tank is opened, old slurry is removed for use as fertiliser and the new charge is added. The tank is then resealed and ready for operation. Dependent on the waste material and operating temperature, a batch digester will start producing biogas after two to four weeks, slowly increase in production then drop off after three or four months. Batch digesters are therefore best operated in groups, so that at least one is always producing useful quantities of gas. Most vegetable matter has a much higher carbon – nitrogen ratio than dung has, so some nitrogen producers (preferably organic) must generally be added to the vegetable matter, especially when batch digestion is used. Weight for weight, however, vegetable matter produces about eight times as much gas as manure, so the quantity required is much smaller for the same biogas production. A mixture of dung and vegetable matter is hence ideal in most ways, with a majority of vegetable matter to provide the biogas and the valuable methane contained in it.

STIRRING

Some method of stirring the slurry in a digester is always advantageous, if not essential. If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of the biogas. This problem is much greater with vegetable waste than with manure, which will tend to remain in suspension and have better contact with the bacteria as a result. Continuous feeding causes less problems in this direction, since the new charge will break up the surface and provide a rudimentary stirring action

TEMPERATURE CONTROL

In hot regions it is relatively easy to simply shade the digester to keep it in the ideal range of temperature, but cold climates present more of a challenge. The first action is, naturally, to insulate the digester with straw or wood shavings. A layer about 50 – 100 cm thick, coated with a waterproof covering is a good start. If this still proves to be insufficient in winter, then heating coils may have to be added to the biogas digester. It is relatively simple to keep the digester at the ideal temperature if hot water, regulated with a thermostat, is circulated through the system. Usually it is sufficient to circulate the heating for a couple of hours in the morning and again in the evening. Naturally, the biogas produced by the digester can be used for this purpose. The small quantity of gas "wasted" on heating the digester will be more than compensated for by the greatly increased gas production.

GAS COLLECTION

The biogas in an anaerobic digester is collected in an inverted drum. The walls of the drum extend down into the slurry to provide a seal. The drum is free to move to accommodate more or less gas as needed. The weight of the drum provides the pressure on the gas system to create flow. The biogas flows through a small hole in the roof of the drum. A non-return valve here is a valuable investment to prevent air being drawn into the digester, which would destroy the activity of the bacteria and provide a potentially explosive mixture inside the drum. Larger plants may need counterweights of some sort to ensure that the pressure in the

system is correct. The drum must obviously be slightly smaller than the tank, but the difference should be as small as possible to prevent loss of gas and tipping of the drum.

ABOVE or BELOW GROUND?

Biogas plants constructed above ground must be made of steel to withstand the pressure within, and it is generally simpler and cheaper to build the digester below ground. This also makes gravity feed of the system much simpler. Maintenance is, however, much simpler for systems built above ground and a black coating will help provide some solar heating. This should make it clear that biogas is not just a dream, but a practical application and use of a waste product. The millions of cattle, pigs and chickens in Hungary produce millions of tons of manure every year, an incredible amount. This can be seen as a valuable natural resource capable of producing combustible gas that would reduce our consumption of irreplaceable natural gas and also a fertiliser more valuable than the raw manure. This would become a valuable source of biogas for power of Hungary, instead of a pollutant of our water sources in the form of runoff towards the sensitive aquifers of the Carpatian basin. Ecologically and economically viable in all cases!