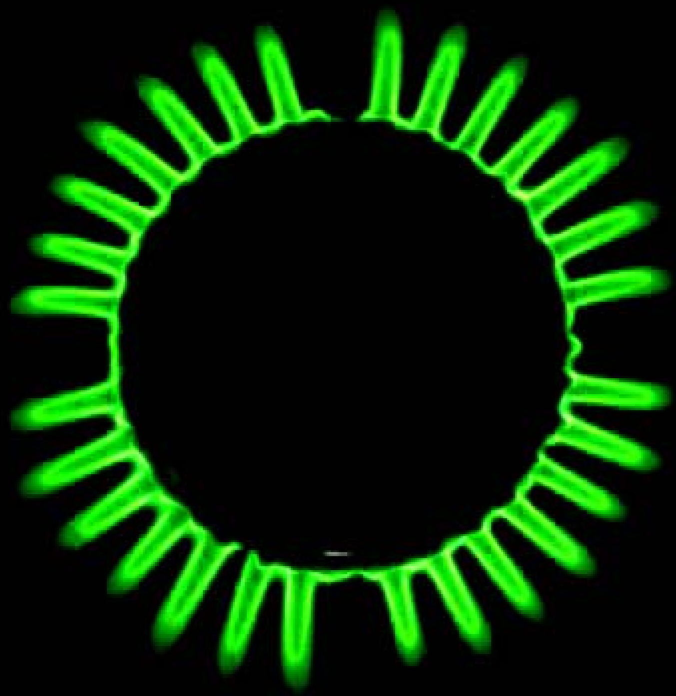


# PROFITING FROM THE USE OF BIOGAS

## THE PANVITA CASE

Roland Tusar, B.Sc.

skupina panvita

www.intering.si

intering HOLDING

# BIOGAS DEFINITION

Biogas is a mixture of different gases like methane, carbon dioxide, hydrogen sulphide, nitrogen and other gases. Presence of all these gases is a result of decomposition of the organic matter.

## BIOGAS PROPERTIES

| | |
|---|---|
| $CH_4$ | 50 – 70 vol % |
| $CO_2$ | 20 – 50 vol % |
| $H_2O$ vapure | 1 – 10 vol % |
| $N_2$ | 0 – 5 vol % |
| $O_2$ | 0 – 2 vol % |
| $NH_3$ | 0 – 1 vol % |
| $H_2S$ | 50 – 5000 ppm |

| | natural gas | biogas | |
|---|---|---|---|
| heat value | 10 | 4 – 8 | kWh/m3 |
| density | 0,7 | 1,2 | kg/m3 |
| ignition point | 650 | 700 | °C |
| explosion limit | 5 – 15 | 6 – 12 | vol % |

Aproksimative formula for anaerobic degradation by Buswell (simplified):

$$C_aH_bO_c \longrightarrow (a/2 + b/8 - c/4)\,CH_4 + (a/2 - b/8 + c/4)\,CO_2$$

Basically the environmental aim of biogas production is reduction of greenhouse emissions and substitution of fossil energy.

## THEORETICAL METHAN YIELD

| | $CH_4$ | l/kg |
|---|---|---|
| Carbonhydrates | 50% | 746 |
| Fats | 71% | 1434 |
| Proteins | 60% | 636 |

# SHORT HISTORY OF BIOGAS

- b.c. - Marco Polo mentions the use of covered sewage tanks in ancient Chinese literature,

-in 1776 - Alessandro Volta concluded that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced,

-in the 1930s - the development of microbiology as a science led to research by Buswell and others in the 1930s to identify anaerobic bacteria and the conditions that promote methane production,

-in 1937 – municipal park cars of several German cities (e.g. Muenchen) ran on biogas from sewage treatment,

-in 1972 – due to the oil-crisis, construction of biogas plants became interesting again,

- today (for instance); in Germany in 1992 there were as few as 100 biogas plants, but in 2005 their number due to favored legislation has increased to 4.000 capable of cumulative power production of nearly 1.000 MW

# WHY BIOGAS IS STILL POPULAR TODAY?

- savings for the farmers,

- improved fertilization efficiency by replacing mineral fertilizer with organic fertilizer (digested slurry),

- less greenhouse gas emission,

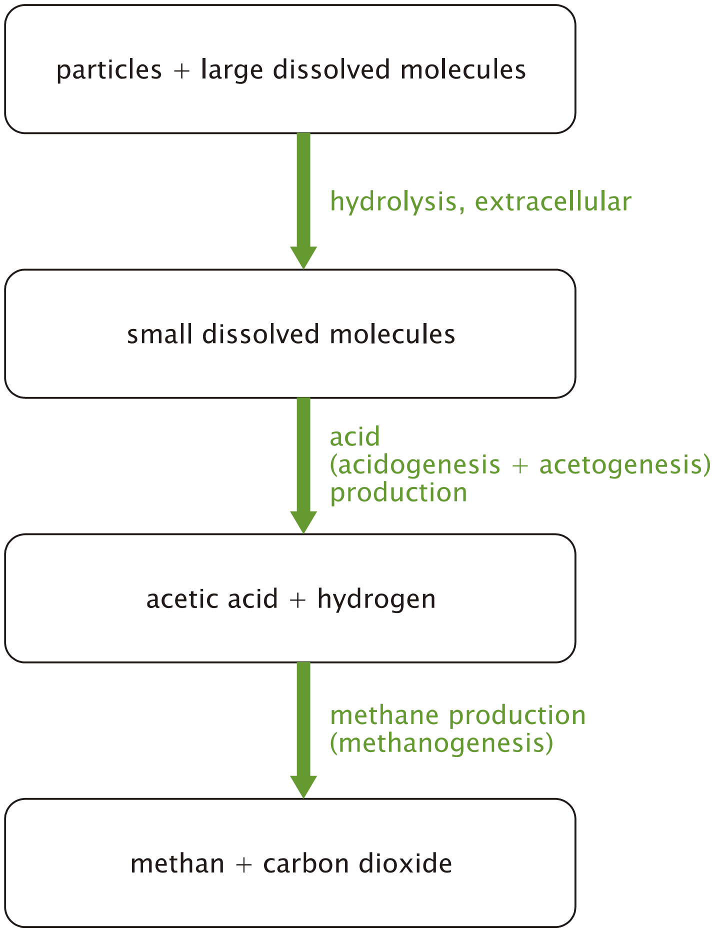
- cheap and environmentally sound waste recycling,

- reduced nuisance from odors and flies,

- pathogen reduction through sanitation, all this connected to renewable energy production,

- less dependent on fuels and natural gas imports

# ANAEROBIC DIGESTION (FERMENTATION)




$$5\ C_6H_{12}O_6 \text{ ————> } 2\ CH_3CHOH \circ COOH + 4\ CH_3CH_2COOH + 3\ CH_3COOH + CH_3CH_2OH + 4\ CO_2 + 2\ H_2 + H_2O$$

5 glucose = 2 lactic acid + 4 propionic acid + 3 acetic acid + ethanol + 4 carbon dioxide + 2 hydrogen + water, or simplified:

$$C_6H_{12}O_6 \text{ ————> } 3\ CH_3COOH$$

The methane production takes place by one of the two processes:

$$3\ CH_3COOH \text{ ————> } CH_4 + CO_2 \quad \text{and}$$

$$4\ H_2 + CO_2 \text{ ————> } CH_4 + 2\ H_2O$$

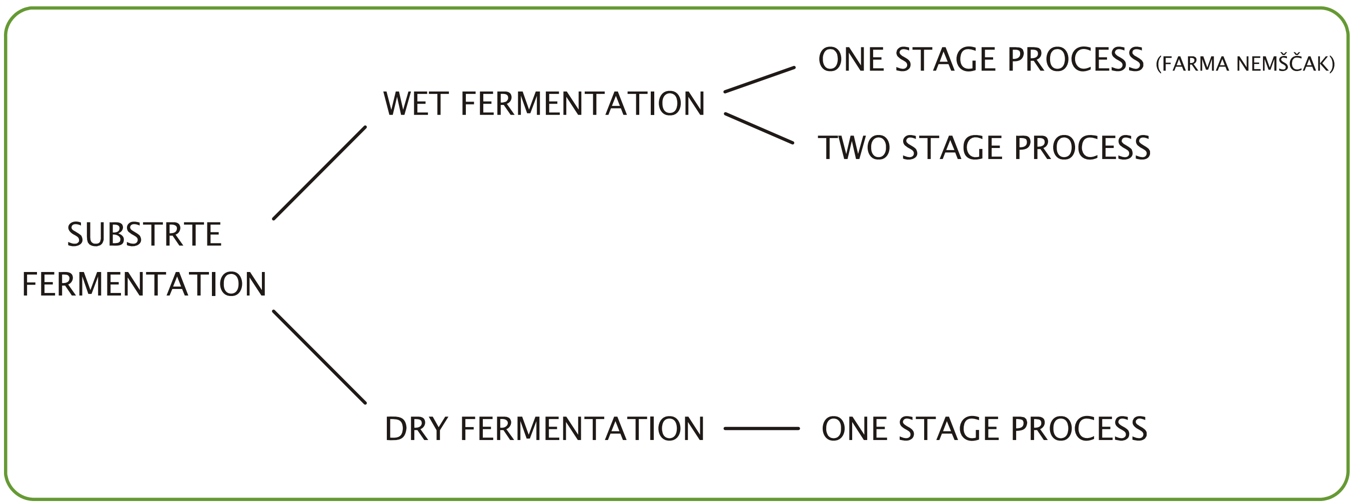
# ANAEROBIC DIGESTION (FERMENTATION)

Methanogenesis is a final step of the process resulting in production of $CH_4$ and $CO_2$, here MO such as acetotrophic and hydrogenotrophic take palce. These MO are very sesitive to T, pH, $NH_3$ and $H_2S$ plus they have very slow repruduction time (1 to 10 days).

*Typs of anaerobic digestion processes with ref. to temperature*

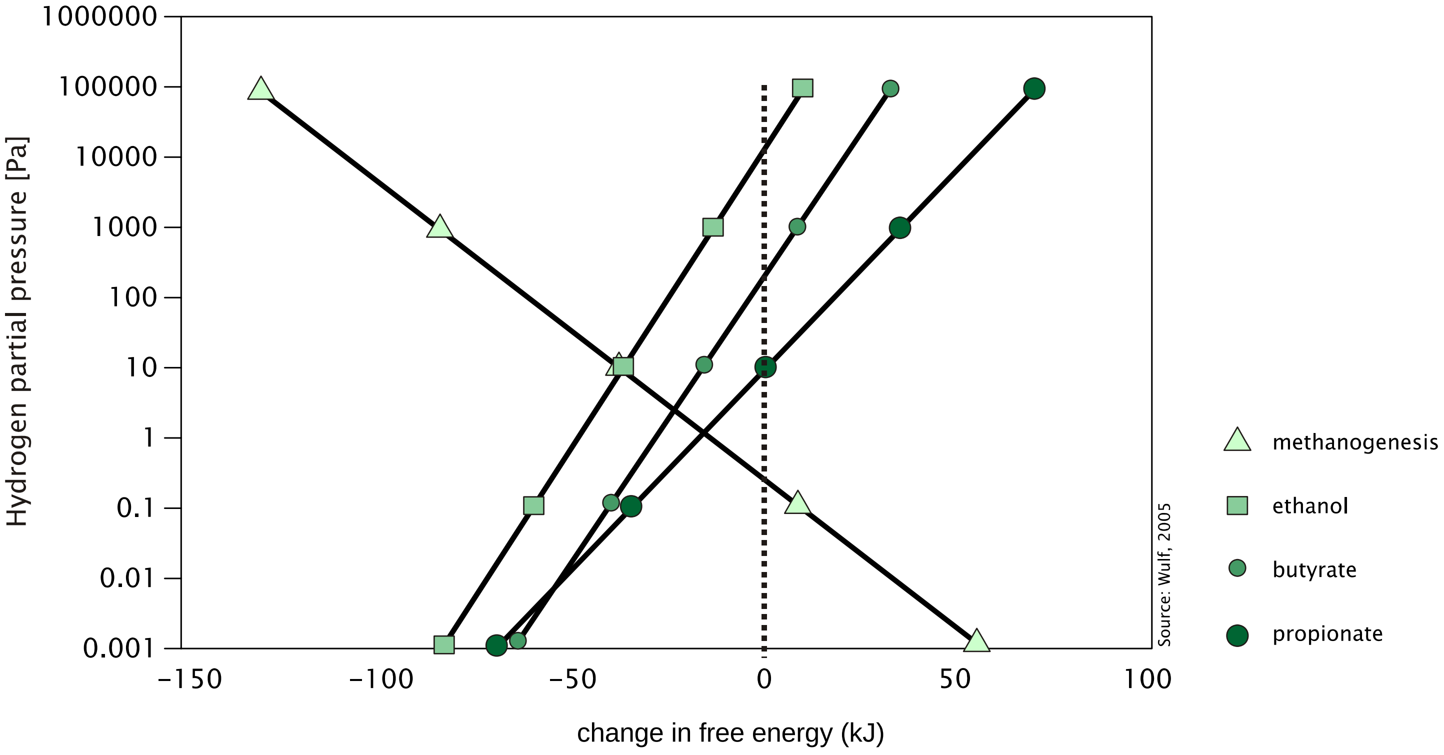
| | |
|---|---|
| cryophilic | under 20 °C |
| mesophilic | 32 – 42 °C |
| thermophilic | 55°C |

*Process of anaerobic digestion (fermetation)*



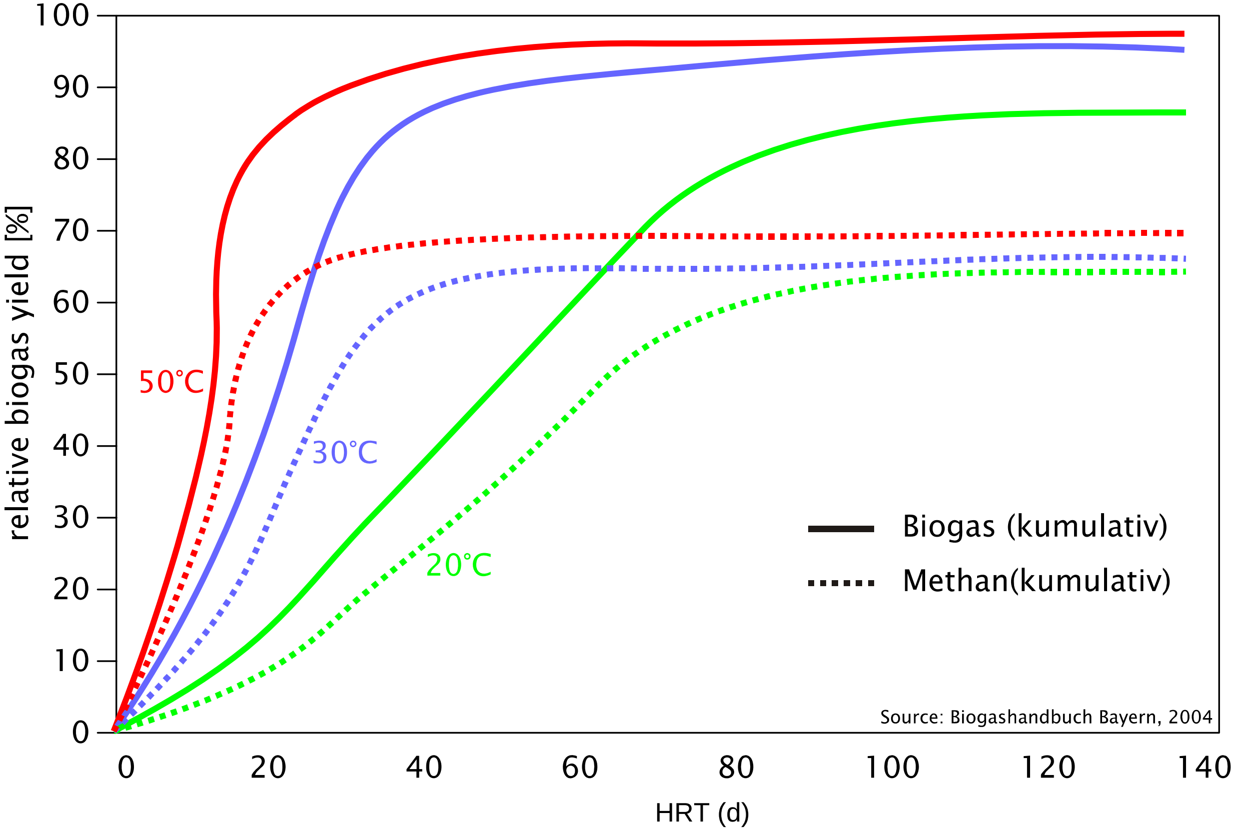
# KEY PROCESS VALUES

## *$H_2$ CONCENTRATION*



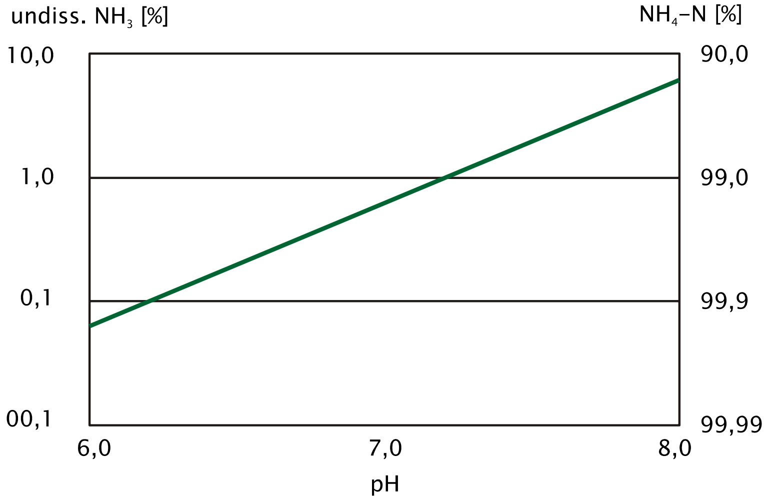
# KEY PROCESS VALUES

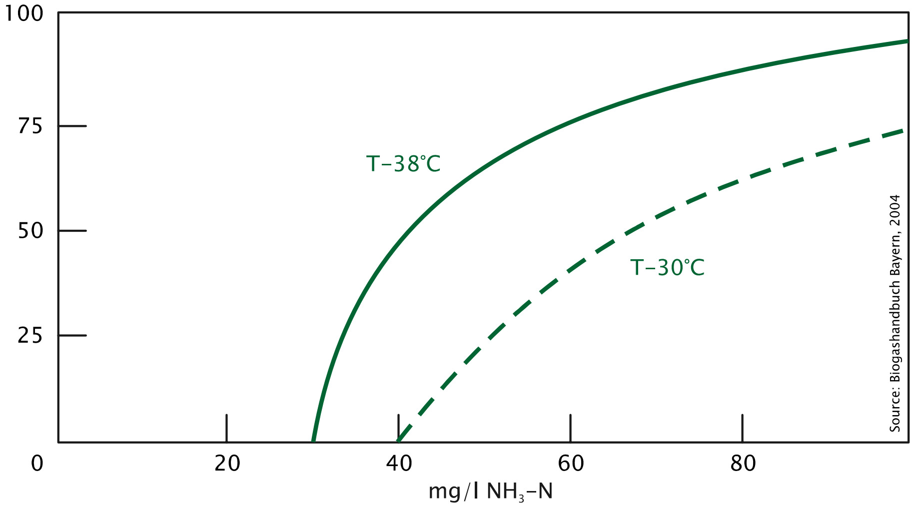
## *TEMPERATURE*



# KEY PROCESS VALUES

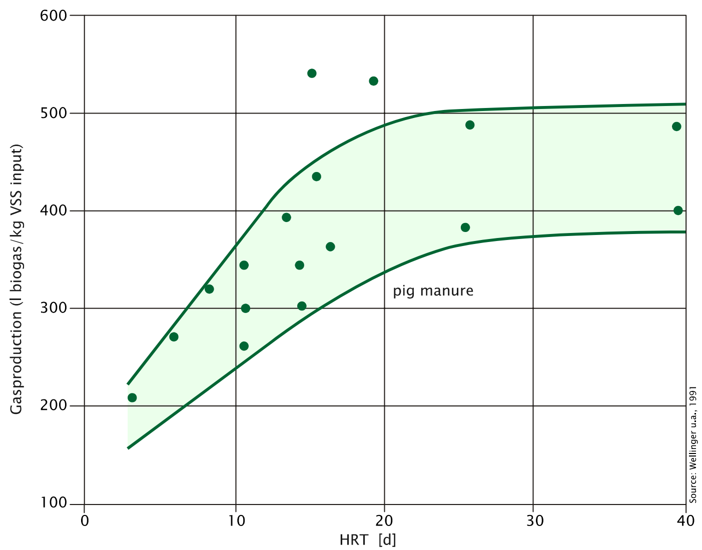
## *pH*

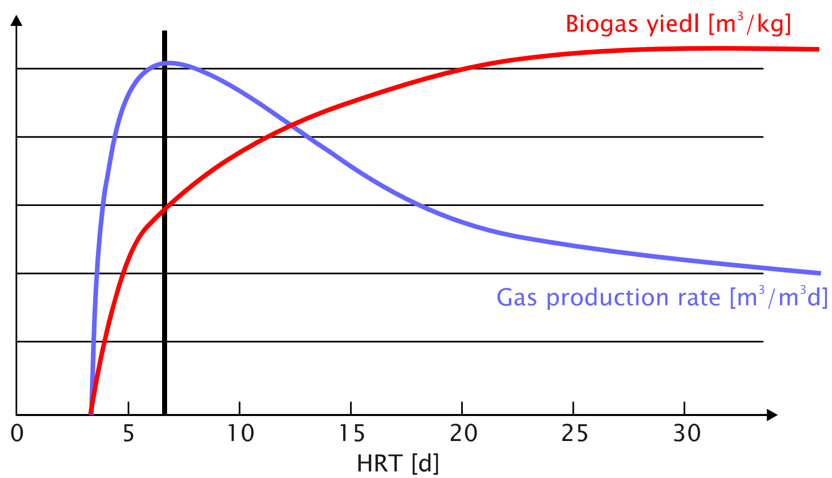


# KEY PROCESS VALUES

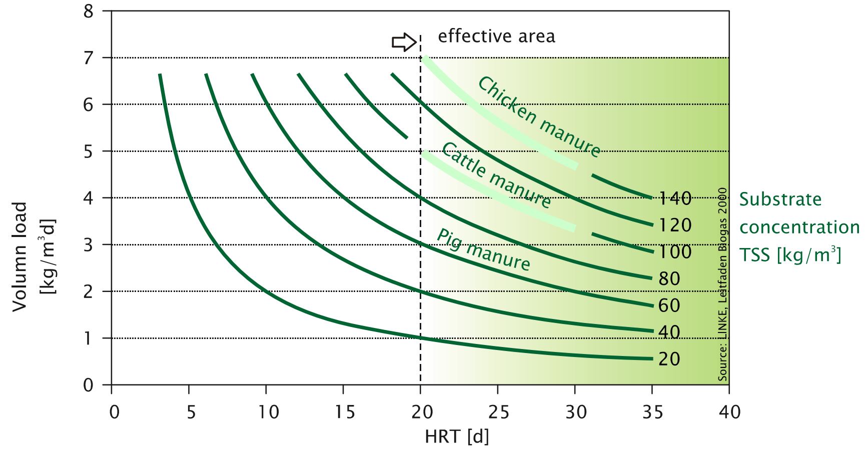
## *HYDRAULIC RETENTION TIME*

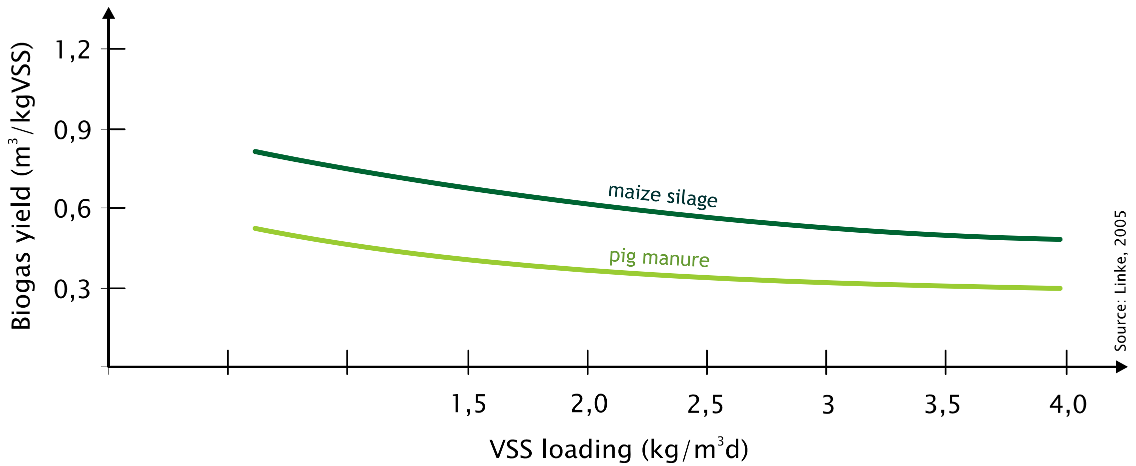


# KEY PROCESS VALUES

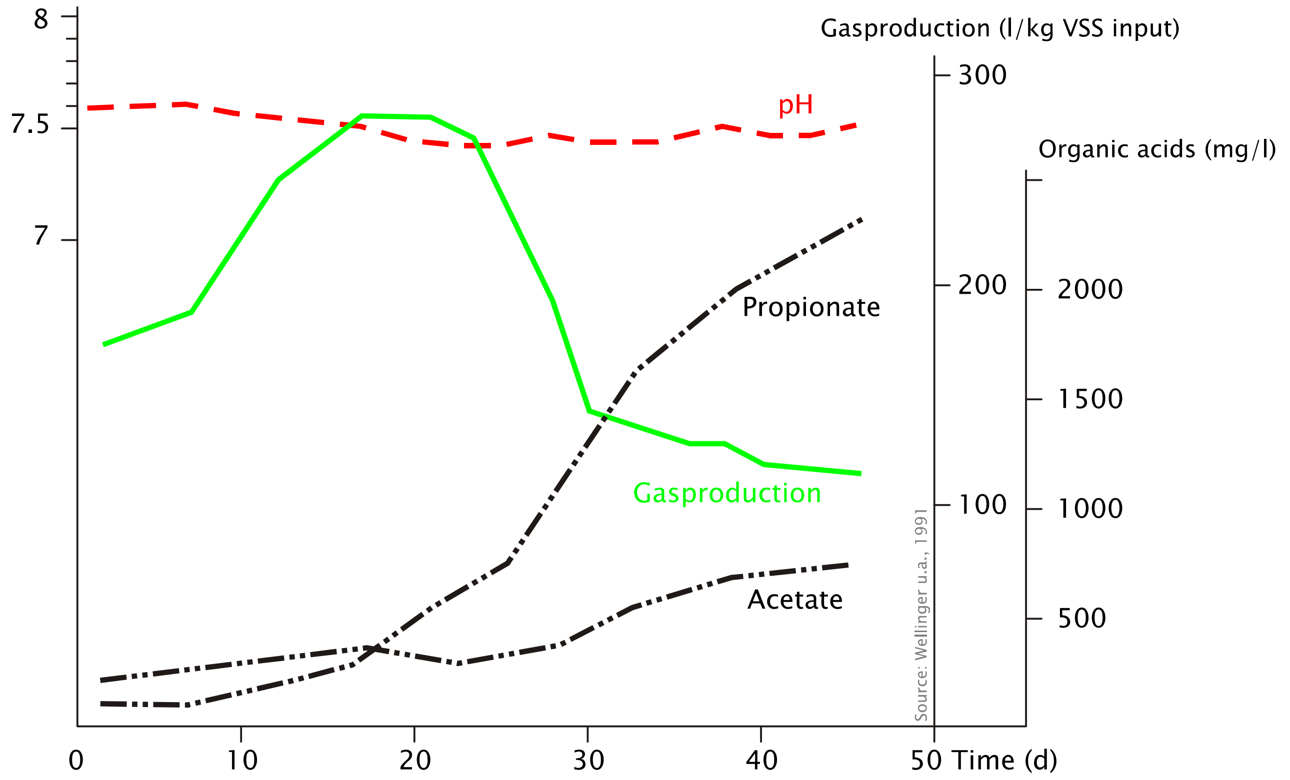
## *VOLUME LOADING*



# KEY PROCESS VALUES

## *OVERLOADING*




HRT: 16d, fresh manure – TSS: 10%, volume loading: 5,2 kgVSS/m3.d

# PRESENT INTEREST IN ANAEROBIC DIGESTION

- an increased recognition, in both developing and industrial countries, of the need for technical and economical efficiency in the allocation and exploitation of resources,

- shifting from the main purpose of energy production, into a multi-functional system:

  a) treatment of organic wastes and wastewaters in a broad range of organic loads and substrate concentrations;

  b) energy production and utilization;

  c) improvement of sanitation; reduction of odors;

  d) production of high quality fertilizer

- R & D has shifted from basic studies on anaerobic fermentation to the digestion of more complex materials that need modified digester designs. The main fields of R & D activities are:

  a) fermentation at high organic loadings;

  b) high rate digestion of diluted waste waters of agro-industries including substrate separation during fermentation; immobilization of the microorganisms;

  c) fermentation and re-use of specific materials in integrative farming systems;

  d) biogas purification;

  e) simple but effective digested design/construction of standardized fermenters;

  f) domestic waste water treatment.

# SUBSTRATE FOR BIOGAS PRODUCTION

| type of substrate | $m^3$/kg.VSS |
|---|---|
| swine manure | 0.40 – 0.55 |
| cattle dung (buffalo, cows) | 0.20 – 0.40 |
| poultry dung | 0.35 – 0.65 |
| horse dung | 0.20 – 0.35 |
| | |
| slaughterhouse waste | 0.20 – 0.80 |
| | |
| maize | 0.45 – 0.70 |
| sugar beet | 0.75 – 0.85 |
| | |
| municipal biowaste | 0.31 – 0.64 |

| Species | Cow | Pig | Chicken |
|---|---|---|---|
| Quantity per year | 22.5 $m^3$ | 2.5 $m^3$ | 60 kg |
| Dry substance | 9% | 7% | 22% |
| Organic dry substance | 80% | 70% | 60% |

# SUBSTRATE FOR BIOGAS PRODUCTION

C/N Optima:

10 – 16 (kaltwersset al, 1998)
16 – 45 (glauser et. al, 1987)

C/N-ratio too small:

Occurrence of toxic ammonia concentrations (from 1500 – 3 ppm)

C/N-ratio too high:

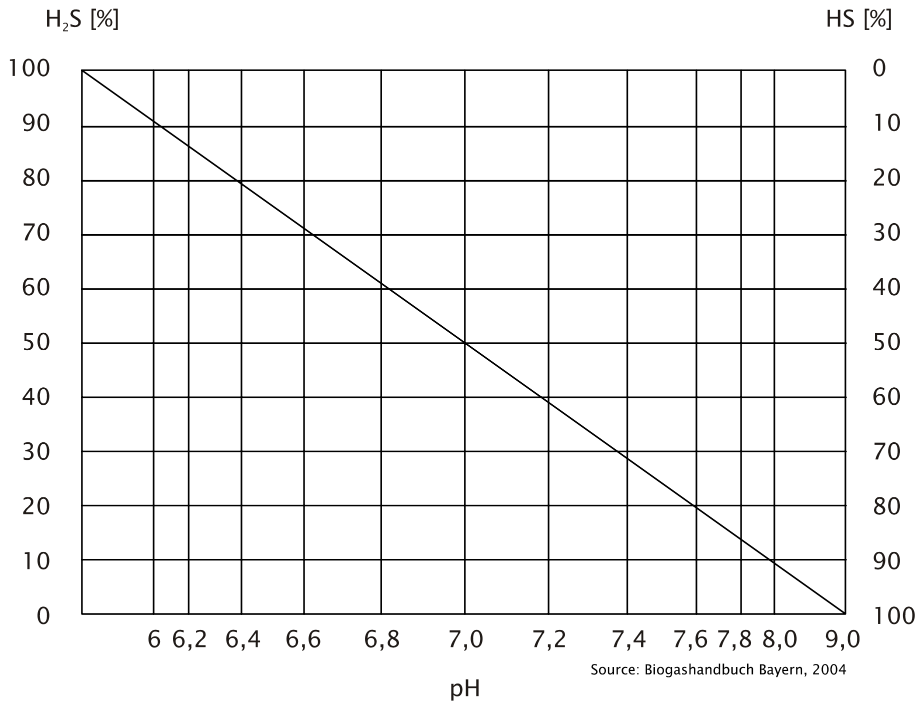
- uncomplete utilization of C-source
- reduction of methanisation rate
- Increase of content of organic acids

## SANITATION

| CATEGORY 1 MATERIAL | CATEGORY 2 MATERIAL | CATEGORY 3 MATERIAL |
|---|---|---|
| All parts of animals that may contain prions which can transmit BSE | Fallen stock, by-products not fit for human consuption and all animal materials collected when treating wastewater from slaughterhouse. Manure and digestive tract content. | Parts of slaughtered animals and fish which are fit for human consuption, or are not fit for human consuption but have no risk for animals and humans: food and catering waste. |
| Must always be destructed by incincration | May be digestet in biogas plant after pressure sterilisation at 133°C for 20 minutes at 3 bar. Hower, manure and digestive tract content may be digestet without pre-tratment | May be digested in biogas plants after pasteurisation at 70°C for 60 minutes with maximum particle size of 12 mm. |

# BIOGAS QUALITY

*S2- ————> HS- ————> H2S*



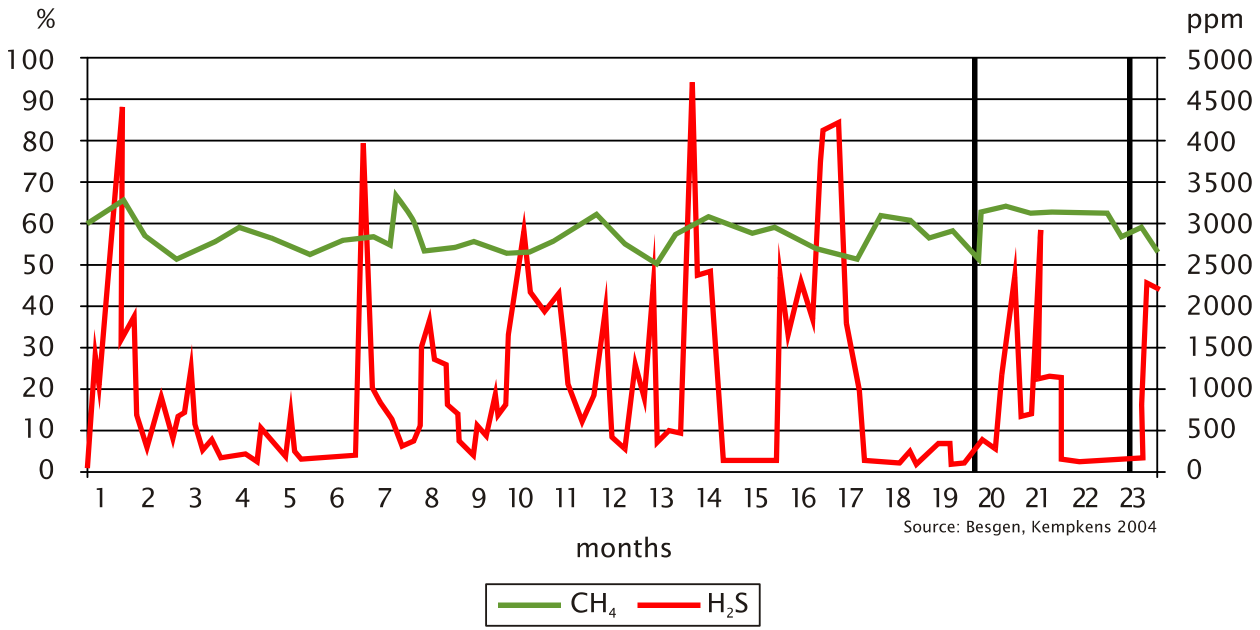

Source: Biogashandbuch Bayern, 2004

health effects:

| Contcetration of $H_2O$ in air (ppm) | effect |
|---|---|
| 0,03–0,15 | smell of rotten eggs |
| 15–75 | headache, vomitting, eye and respiration problems, inconsciuosness |
| 150–300 | loss of smell sense |
| >375 | death after a few hour |
| >750 | death within 30–60 min |
| >1000 | fast death |

# BIOGAS QUALITY

*$H_2S + H_2O$ ————> $H_3O^+ + HS^-$*




**Methods for H2S elimination:**

- biochemical oxidation by dosing 3-5% of air inside or outside digester
- chemical elimination by dosing salts (Fe++) into gas stream

**Common use of biogas in Europe:**

- in CHP (combined heat and power units e.i. co-generators)

For the CHP the biogas quality concerning H2S is required to be less then 600 ppm.

# DIGESTED SLURRY (EFFLUENT) MANAGEMENT / TREATMENT

**Effects of digestion on slurry properties:**

– reduction of COD up to 85%,
– nitrogenous compounds are mostly in form of $NH_4$+ while total nitrogen stays unchanged,
– volatile organic compounds are reduced (elimination of odour causing components),
– no changes to P
– increase in pH

**The fermentation process results in:**

– less organic loading for aquatics
– improved N - availability
– possibility of NH3 loss

# DIGESTED SLURRY (EFFLUENT) MANAGEMENT / TREATMENT

Two kinds of slurry disposal are possible:

- direct use on fields of non separated slurry using different techniques as splashing, trailing or injection,
- separation of solid and liquid part of the slurry using filtering techniques (separators, centrifuges, filter belt presses etc)
    - o scattering of the solid part on the fields
    - o further treatment of the liquid part befor discharging into water recipient

Possible methods (BAT) for further treatment of liquid part of the slurry:

- stripping of ammonia
- ion – exchange processes
- membrane filtration / reverse osmosis
- biological treatment (aerobic)
- chemical treatment (adsorption/absorption)

| | TS% | VSS %TS | Ntot %TS | NH4–N %Ntot | P2O5 %TS |
|---|---|---|---|---|---|
| swine slurry | 5 – 8 | 80 | 6 – 18 | 50 – 95 | 2 –10 |
| maize residual sludge | 26 – 35 | 70 – 95 | 3,5 – 7,0 | 6,9 – 19,8 | 0,38 – 0,76 |

After separation approximately 80% of phosphorus and 20% of nitrogen is kept in solid part of the slurry useable as a fertilizer.

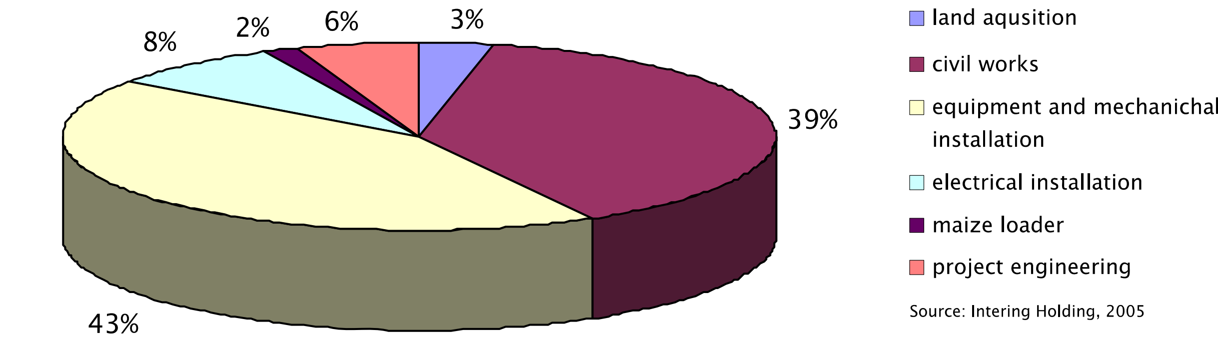
# PROFITABILITY OF BIOGAS PRODUCTION

**Basically there are six folds of consideration:**

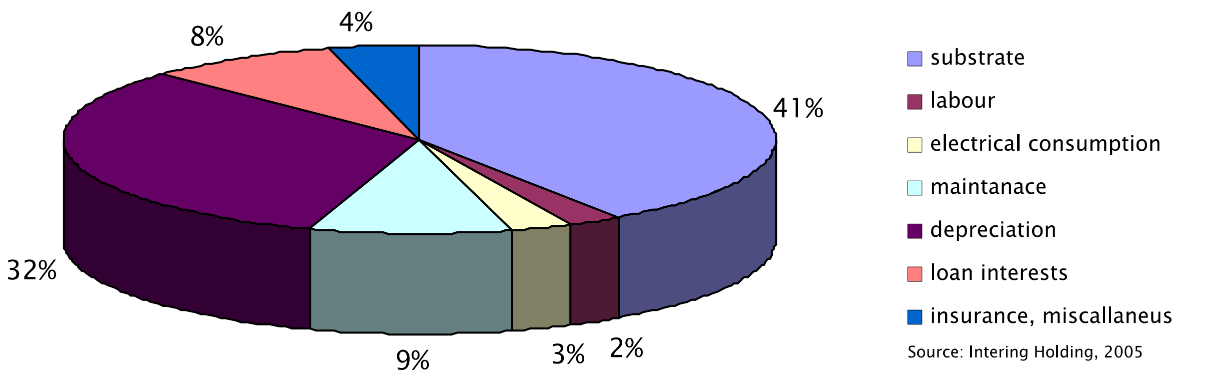
- cost of substrate (seeding, harvesting, transport, ensilaging)
- specific operational cost of biogas technology
- revenue from substrate - if applicable (i.e. tipping fee)
- revenue from electricity (at fixed unit price per kWh of generated electrical power)
- revenue from nutrients
- revenue from heating supply to external consumers – not very often

# PROFITABILITY OF BIOGAS PRODUCTION

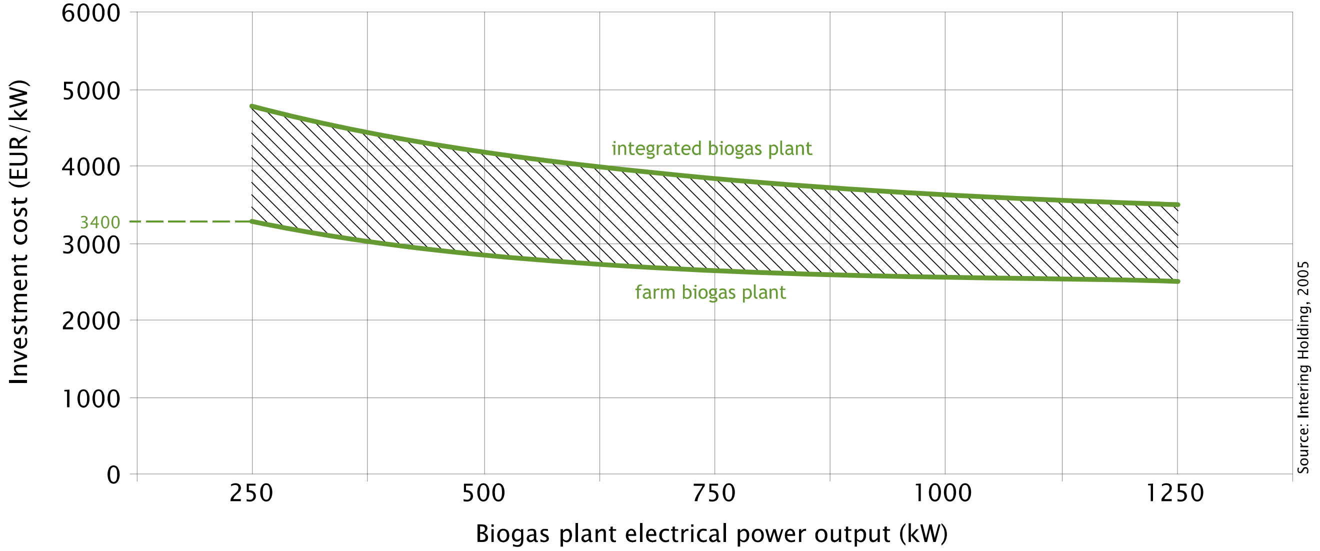
capital costs

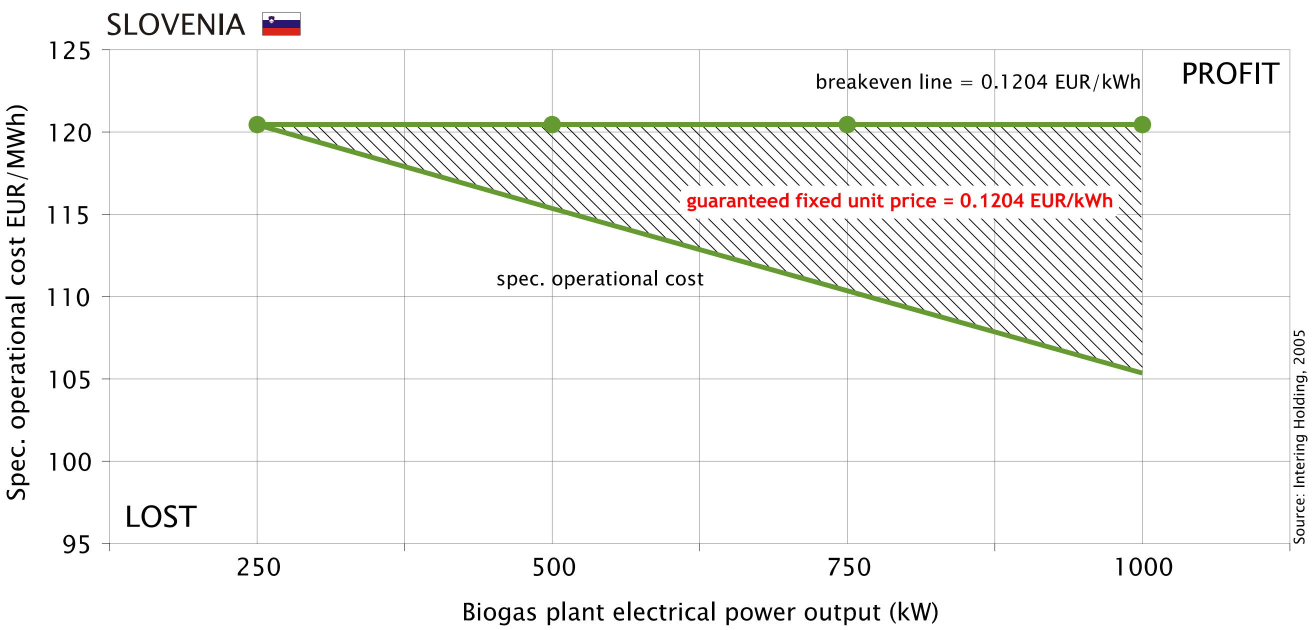



operational costs



# PROFITABILITY OF BIOGAS PRODUCTION



# THE PANVITA CASE

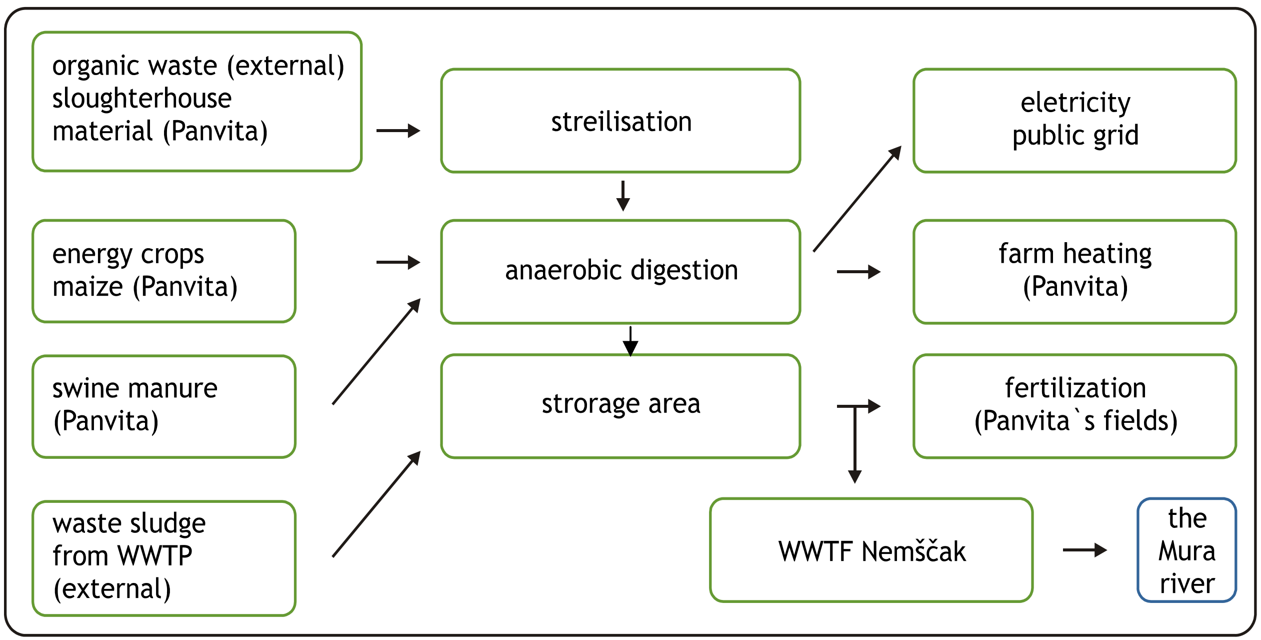
## PROJECT ID

Project builder: Intering Holding, Roland Tušar, B.Sc.
Project operator: KG Rakican - Ekoteh
Substrate supplier: Panvita group of companies
Digested slurry up-taker: Panvita group of companies

## PROJECT INVESTMENT

Total investment: 6,4 mio EUR
Biogas plant: 4,8 mio EUR or 3.680 EUR/kWel
Sterilization plant: 1,3 mio EUR
Storage area: 130.000 EUR

## BIOGAS PLANT NEMŠČAK - PROJECT STREAM



# THE PANVITA CASE

## SUBSTRATE

maize 12.000 T/y
swine manure 58.500 m3/y
slaughterhouse waste - 2nd and 3rd category : 4.500 T/y

| INCOMES | COST |
| --- | --- |
| Teeping fee for reception of 2nd an 3rd category material | plant running cost |
| Teeping fee for reception of mineralized organic sludge | substrate (maize) |
| Electricity supply to the public grid (at fixed unit price acc. To 10 years contract with authorities) | depreciation |
| Remote heating of the farm | cost for purification of the centrate on the WWTF Nemščak |
| Supply of nutrient to agricultural fields | |

## REVENUES SPLIT UP

| electricity | fees | heating |
| --- | --- | --- |
| 63% | 30% | 7% |

## PROFABITILITY CALCULATION

Gross Profit = Incomes – Costs
Net Profit = Gross Profit - Taxes
Cash Flow = Net Profit + Depreciation
ROI = Investment / Cash Flow (in years)

# THE PANVITA CASE

| PANVITA | SUBJECT | BEFORE | AFTER | CO2 SAVING | COST SAVING |
|---|---|---|---|---|---|
| MIR - Meat processing plant | animal by-products - waste material | 3.000 tons per year of category 2 and 3 is produced and collected by service company | co-fermetation in biogas plant | | |
| Agromerkur - Poultry plant | animal by-products - waste material | 2.000 tons per year of category 2 and 3 is produced and collected by service company | co-fermetation in biogas plant | | |
| Pig`s breeding farm Nemscak | farm heating | 600.000 l/year of fuel oil | co-generation on biogas | | |
| Agricurtural divison KG Rakičan | fertilization | mineral fertilizer - N,P, K 80 tons | organic fertilizer as digested slurry from biogas plant | 9.000 T/Y | 650.000 €/Y |