Designing a biogas plant – which factors are relvevant and how can we measure them?

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CHAPTER 1: Basics

Basic parameters for designing

- oLR = Organic load rate
- HRT = Hydraulic retention time
- DM = Dry Material
- oDM = organic Dry Material
- COD = Chemical Oxygen Demand
- Gas Production Rate

- $olR = \frac{\dot{m} * c}{V_{R} * 100}\ [kg\ oDM\ *\ m^{-3} * d^{-1}]$
- $HRT = \frac{V_R}{\dot{V}}\ [\mathrm{d}]$
- DM = Drying at 105°C
- oDM = Organic Material after carbonization at 550°C
- COD = Standard Water parameter
- Gas production Rate = Based on Tests or literature

Designing – A finding process

- **What can be generally said?**
- - Each biogas plant have to be uniqe!
- - Design depends on the region, input materials and availability, gas using, selling price of heat and power etc.
- - Fermentation residues handling – is a separation in solid and liquid phase necessary? Can we upgrade and sell them? Do we have to take care of pathogenes? Will they used as fertilizer on the fields?

Designing – A finding proces

- How can we reach information about the input materials?
- \- Literature?
- \- Batch fermentation tests?
- \- DM, oDM, FoDM calculations?
- \- COD Value?
- \- Heating Value, TOC, Elementary Components?
- How reliable are these possibilities?
- \- Literature values are middled values of hundreds of fermentation tests – But are they corresponding with your substrate?
- Batch fermentation test – Is an easy and cheap way to reach information about the gas production – BUT: Depends on the Inoculum…

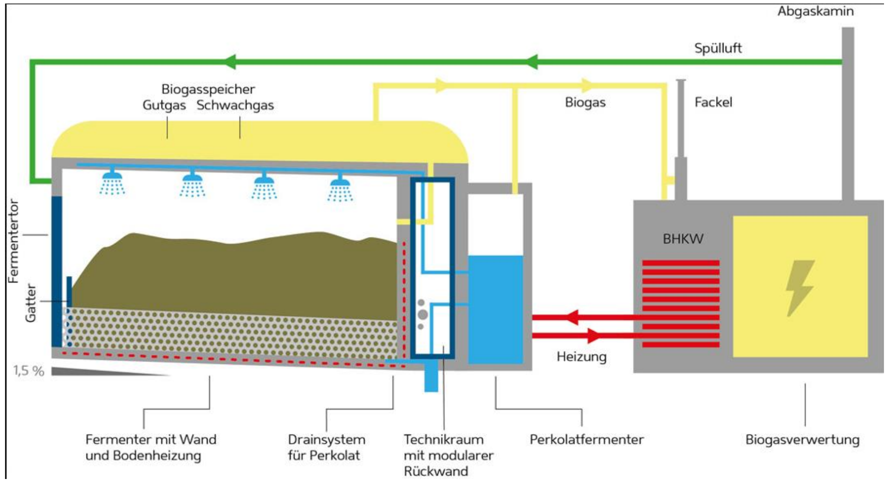
Design – A finding process

- - DM, oDM and FoDM calculations are mainly based on historical observations and empirically calculated correction factors
- - COD – test mainly used for waste water. Problem with solid materials…
- - Heating value: Easy and cheap way to determine the total energy content. BUT: Currently no information about the digestability…
- - TOC: Using measured data sets, system boundaries can include the biogas plant as a whole, single samplings not representative, no determination for the degradable energy is possible
- - Elementary compounds: Using historical data and emipric defined factors

- -> In the end you have to decide and you need to find reliable results for the gas production. Most common are Batch-fermentation tests and you make a discount (10 – 15% off)

CHAPTER 2 – Designing a Plant

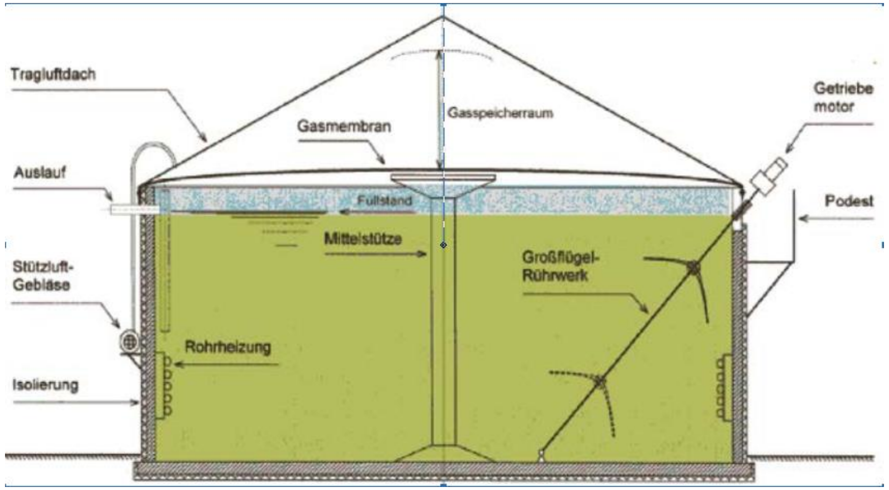
Designing a Plant – Different fermenter types



Source: www.bekon.eu

- **Batch garage fermenters**
- + high DM content possible
- + easy to handle and low cost design
- + easy to maintain
- - low and non constant gas production
- - no pumpable materials
- - high emissions

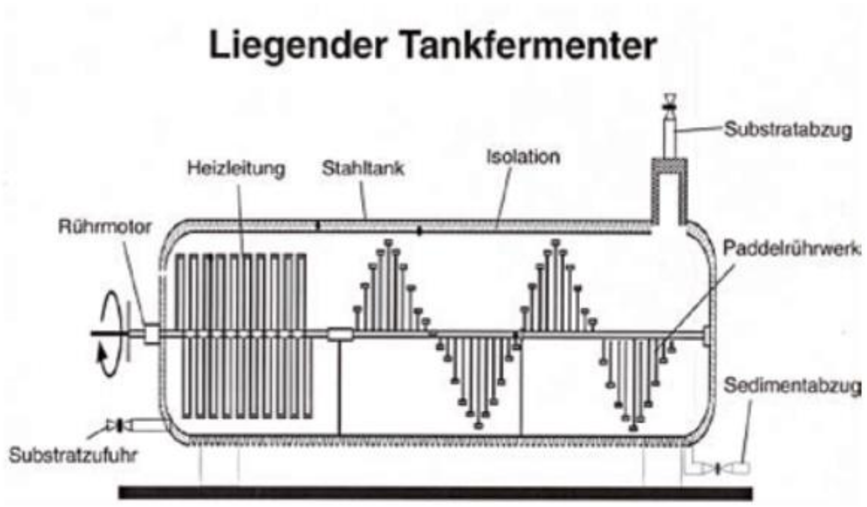
Designing a Plant – Different fermenter types



Source: FNR Handreichung Biogas 2013

- **Complete Stirred Tank reaktor**
- + Easy to handle
- + easy to maintain
- + suitable for the most materials (pumpable)
- - no defined retention time
- - sinking and swimming layers
- - no separation between the biogas phases

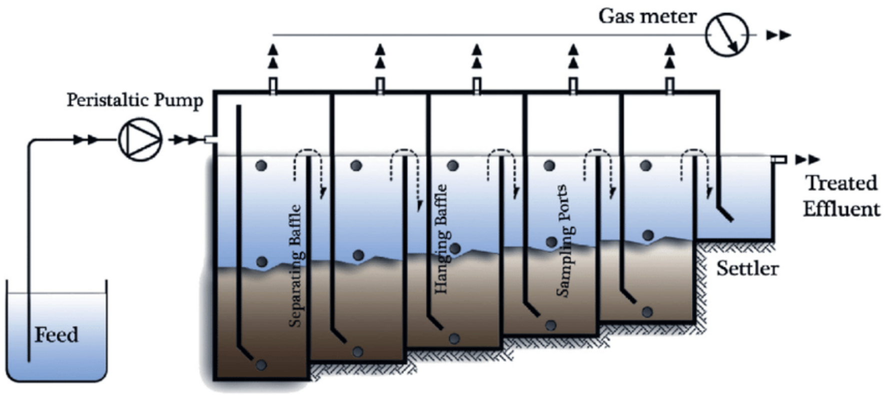
Designing a Plant – Different fermenter types



Source: FNR Handreichung Biogas 2013

- **Plug Flow Fermenter**
- + High DM content possible (pumpable)
- + easy and cheap to build
- + no sinking and swimming layers
- + separation of gas production phases
- - Recirculation with bacterias
- - maintenance hard to realise

Designing a Plant – Different fermenter types



Source:
https://www.google.de/search?q=anaerobic+baffled+reactor&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjJm8vhk_7cAhUQhxoKHVGYCxYQ_AUICigB&biw=1224&bih=872#imgrc=c0Xz25-36R73NM:

- **Anaerobic baffled reactor**
- + No moving parts (stirrer etc.)
- + No maintanance necessary
- + Seperated gas production phases
- - Sinking layers
- - Only for low viscouse mediums

Designing a Plant – Different fermenter types

- **What can be generally said?**
- Depending on the input materials the fermenter type have to been chosen
- Each fermenter type has its advantages and disadvantages
- - Maintenance, Gas losses, price, Heat demand etc.

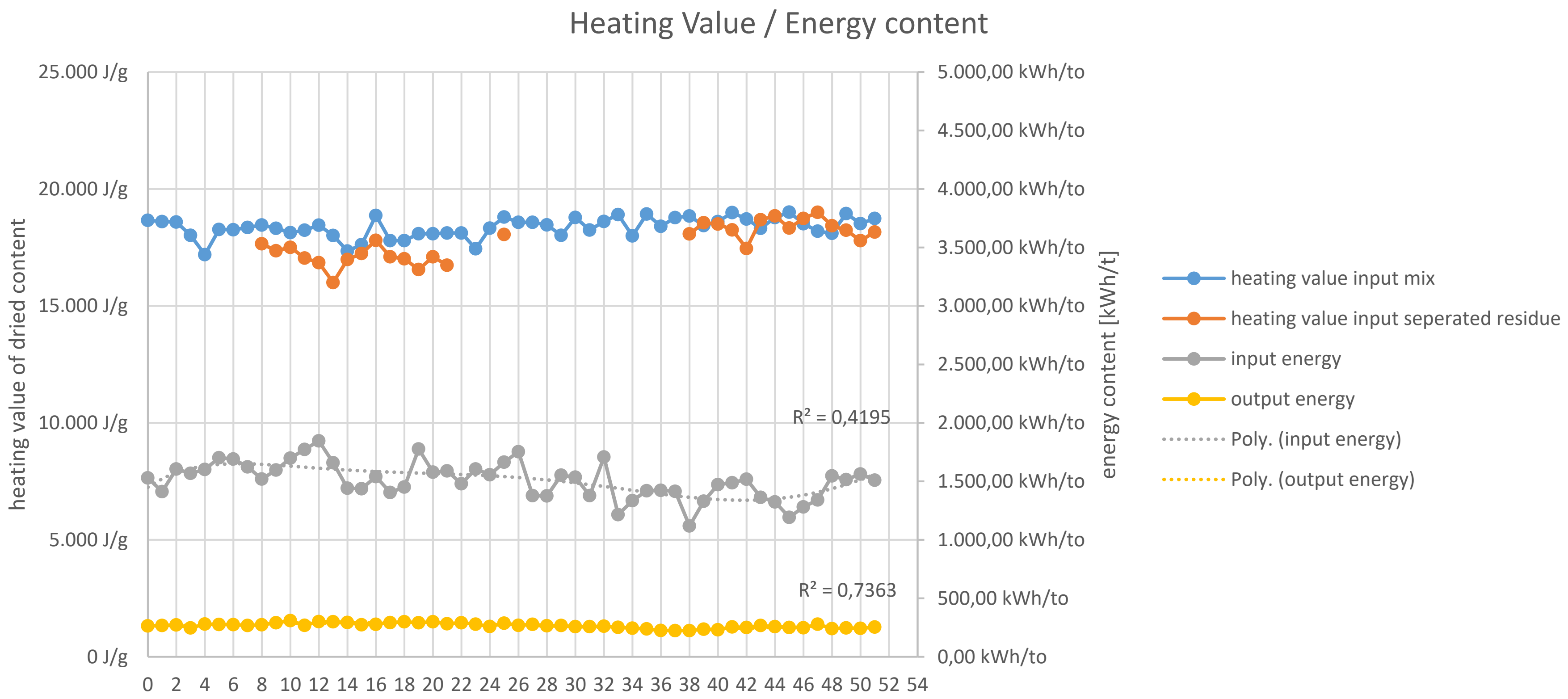
- Overall conclusion: Before building up a fermenter check your input materials!

Time series analysis of a currently operating plant for measuring the efficiency

- Time series analysis allows to show the influence of:
- - process management
- - quality changes of input materials
- - repowering initiatives – pretreatment etc.

- For time series analysis it is necessary to know about:
- - input materials (quality and quantity)
- - output material (quality and quantity)
- - constantly delivered samples of the materials (in min. for one hydraulic retention time of the analysed plant)

Results of a 1 year time series analysis



average efficiency	Min.	Max.	Standard deviation
82,22%	78,95%	84,84%	1,71%

Correction factors for time series analysis

- For correct calculation of the efficiency following correction factors are necessary:
- - mass of Sulphur and Nitrogen of the samples
- - volatile organic substances
- - losses of CHP / Gas Upgrading Module
- - losses of permeation by the roof and concrete
- - leachate water of stored biomass; quantity and quality
- - self consumption of bacterias
- - rain water (mass)
- - output material (mass)
- - self consumed electric and heat energy by the plant

Influence of leachate- and rain water

Month	Input-Material	Rain-Water	Leachate-Water	Retention time F1 and F2	Retention time of fermenters 1-3	Total retention time of fermentative system
May	2.046,52 to	349 m³	0 m³	38,20 d	70,03 d	101,86 d
Jun	2.267,39 to	379 m³	0 m³	34,57 d	63,38 d	92,19 d
Jul	1.978,02 to	496 m³	0 m³	36,99 d	67,81 d	98,64 d
Aug	1.898,21 to	496 m³	0 m³	38,22 d	70,07 d	101,92 d
Sep	2.535,64 to	490 m³	466 m³	26,21 d	48,05 d	69,89 d
Oct	2.439,16 to	490 m³	466 m³	26,95 d	49,42 d	71,88 d
Nov	2.327,09 to	551 m³	0 m³	31,79 d	58,29 d	84,78 d
Dec	2.196,90 to	477 m³	0 m³	34,22 d	62,73 d	91,24 d
Jan	2.038,27 to	428 m³	0 m³	37,09 d	68,01 d	98,92 d
Feb	2.300,03 to	257 m³	0 m³	35,78 d	65,60 d	95,42 d
Mar	2.356,08 to	337 m³	0 m³	33,98 d	62,30 d	90,62 d
Apr	2.351,86 to	306 m³	0 m³	34,43 d	63,11 d	91,80 d

average retention time	**Min.**	**Max.**
90,76 d	69,89 d	101,92 d

Conclusions – Measuring the energy efficiency

- Complete mass and energy balances are not possible for now, due to the named correction factors
- To create these balances, general correction factors for each type of biogas plants have to be found
- The method is only valid for biogas plants, using energy crops and manure as input. It is not valid for waste water treatment plants and for slaughterhouse waste
- An extension of the method can be the calculation of degradable energy to show the residual-gas-potential of the used input materials
- To see the influence of input material changings and changing of the process management, the time series should be roughly three times of the hydraulic retention time

Large Scale Bioenergy Lab 2

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