

Low cost small scale biogas plants for liquid agrobiomass as a development potential for the Serbian Biogas market

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Who we are

Anaerobic digestion
Technology development

- Pre-treatment
- Fermenter Technology
- Products Upgrading
- Control

Closing nutrient loops

- Algae as nutrients collectors are digested
- Biogas in artificial food cycles (Hydroponics, Aquaculture, etc.)



Renewable Energy Systems
Integration

- Methanation
- Methanol Synthesis
- Power to Chemicals

Process integration in
Biorefineries

- Waste valorization in Food Industries
- Efficiency studies

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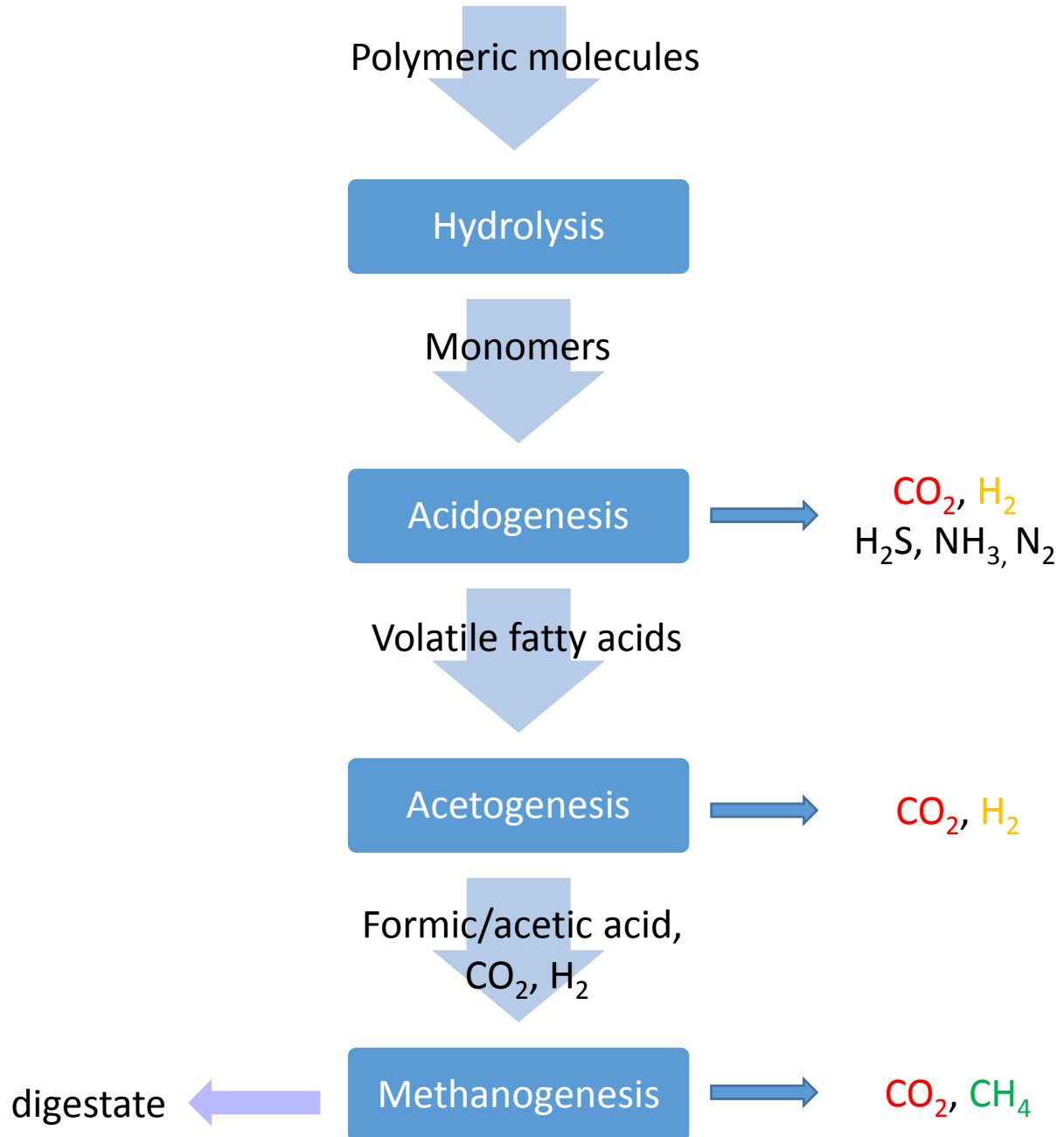
<http://www.znes-flensburg.de>

<http://cats.fh-flensburg.de>

Reasons for Choosing Biogas Technologies

Substrate	Main Goal	Attractive Goal	Additional Goal
Wastewater	Disposal/COD Reduction	Nutrients Recycling	Energy Production
Waste	Disposal	Nutrients Recycling	Energy Production
Manure	Nutrients Recycling	Disposal	Energy Production
Energy Crops	Energy Production		
Residues Biorefineries	Disposal	Energy Production	Nutrients Recycling

Biogas process



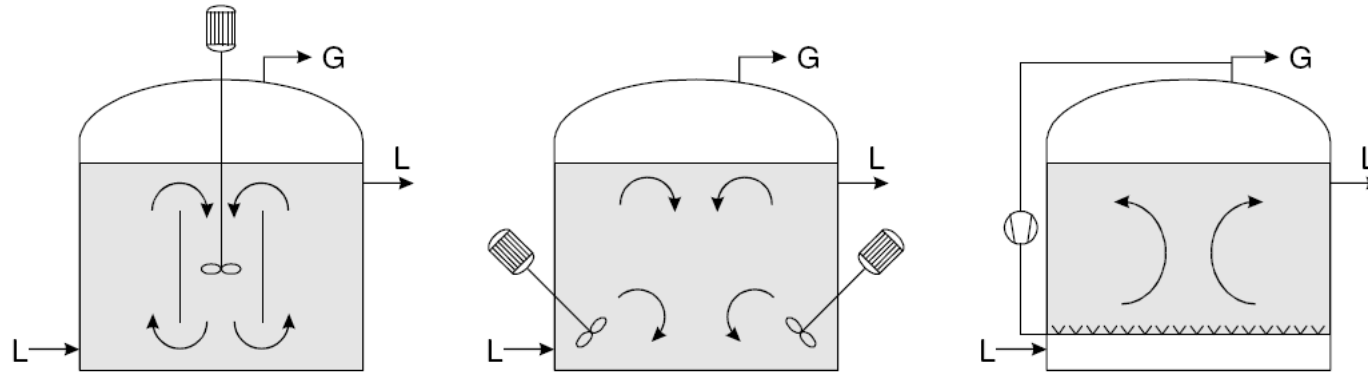
Common Understanding of the Process Conditions of Anaerobic Digestion

	Hydrolysis Acidification	Acetification Methanation
pH-Value	5,0 – 6,5	6,7 – 7,5
Temperature	25 – 35°C	33 – 42°C (mesophil) 50 – 58°C (thermophil)
C/N-Ratio	10 – 45	20 – 30
Nutrients Ratios C / N / P / S	500 / 15 / 5 / 3	600 / 15 / 5 / 3
Trace elements	Keine spezifische Ansprüche	Ni, Co, Mo, Se (essentiell)
Doubling rate	24 – 36 hours	10 – 15 days

Weiland (2001) „Grundlagen der Methanvergärung“ and own Results

Common Fermenter Technology

Vollständig durchmischte Reaktoren



Weiland, 2006

Conditions in CSTR

- homogeneous distribution of all individual Components in the fermentation brewth
 - and in the outlet L. Flow rate of each individual component* is product out of its concentration and the volumetric flow rate
- ⇒ Volume and volumetric flow have to adapted to biochemical reactiond and bakterial growth rates, i.e long hydraulic retention times
- ⇒ conditions are equal for all mikroorganismen, i.e. suboptimal

*Components are micro organisms, substrates, intermediates and products

Fermenter Technology - Cascades

Fermenter cascades— adaption of process condition to particular optimal microbial conversion rate

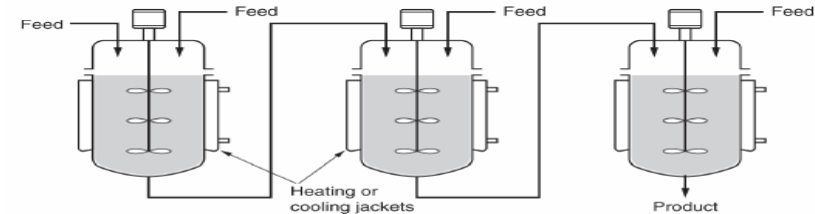
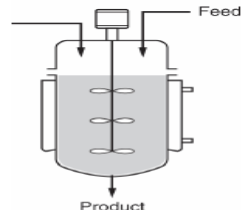


Figure 1-2 Battery of stirred tanks. [Excerpted by special permission from *Chem. Eng.*, 63(10), 211 (Oct. 1956). Copyright 1956 by McGraw-Hill, Inc., New York, NY 10020.]

OLR [kg(oDM)/(m ³ *d)]	Feed [g/d]	Biogas Yield [m ³ /t(oDM)]	Spalte1 [L(G)/(L(F)*D)]	pH F1
2	27	721	1,7	7,3
4	54	725	2,9	7,3
6	81	701	4,2	6,8
8	108	454	3	6,5
10	135	100	1	6,1

OLR [kg(oDM)/(m ³ *d)]	Feed [g/d]	Biogas Yield [m ³ /t(oDM)]	Spalte1 [L(G)/(L(F)*D)]	pH F1	Spalte2 F2	Spalte3 F3
2	81	740	1,5	7,2	7,3	7,3
4	162	741	2,9	6,6	7,4	7,4
6	244	747	4,4	5,8	6,8	7
8	325	745	5,9	4,7	6,5	7,3
10	406	713	7	4,6	6,3	7,1

OLR: Organic Loading Rate
oDM: Organic Dry Matter

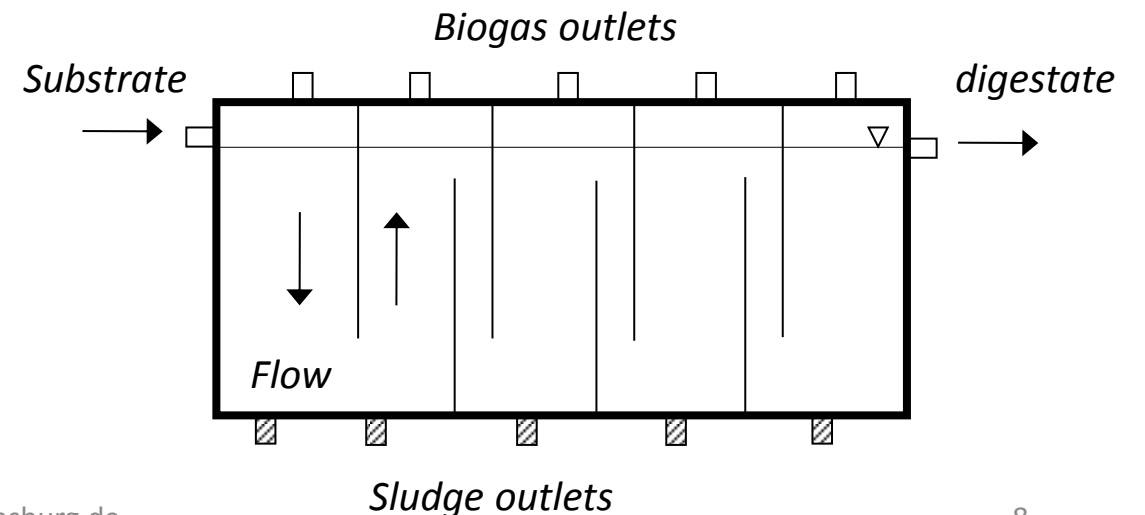
High Performance Biogas Technology

Since several years we are developping high performance biogas technology:

- Small scale, compact, robust, flexible, adapted to optimal microbial efficiency, standardised as container solution

Result: Multi-chamber Plugflow Fermenter called
Multifunctional Anaerobic Baffled Reactor

Construction Principle:



High Performance Biogas Technology

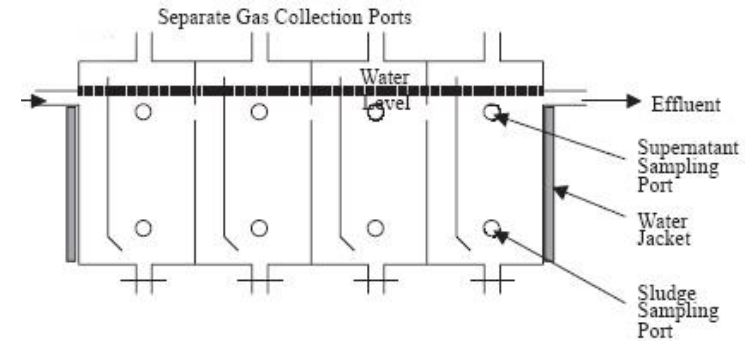
	1. Compartment	2. Compartment	3. Compartment	4. Compartment
pH-Value	4,5 – 7,0	5,5 – 7,2	6,8 – 7,3	7,0 – 7,3
Methane	0 – 20%	5 – 30%	50 – 60%	55 – 70%
Carbon Dioxide	50 – 80%	55 – 65%	40 – 50%	30 – 45%
H ₂ -producing bacteria	predominant	dominant	low	bld
Methanosaeta Methanosarcina	low	low	predominant	dominant
Dominant Process	Hydrolysis and Acidification		Acetification and Methanation	

1st Biogas microbiology conference , Leipzig 2011, Functional Community Dynamics in a Lab-scale Anaerobic Baffled Reactor for *in situ* Biogas Upgrading

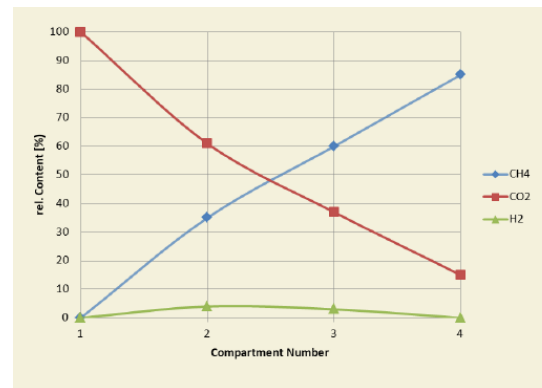
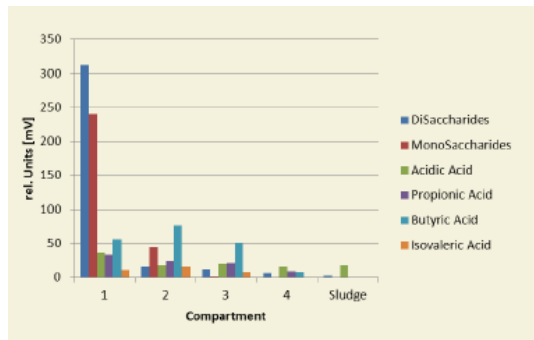
Fermenter Technology - MABR

Combination of Cascades and Biofilms

- ▶ Multifunctional Anaerobic Baffled Reactor: n compartments with settling surface
- ▶ Option for inherent biorefinery and internal gas separation
- ▶ Simple and robust container solutions
- ▶ Offers the opportunity for internal gas separation



MABR



High Performance Biogas Technology

Process

Advantages of MABR

Multicompartment fermenter with spatial separation of the complex anaerobic digestion process:

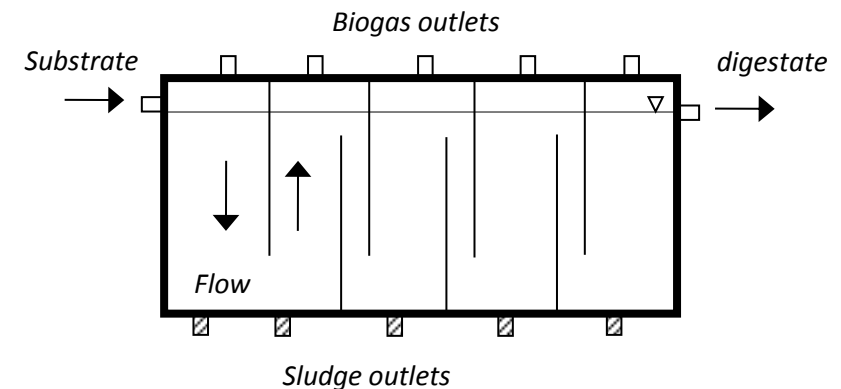
- much faster process
- Robust to shock loads
- Fixed bed fermentation
- Decoupling of HRT and SRT
- High OLR
- Reduced fermenter volumes
- Exactly controlled retention time for the substrates

Constructive

Advantages of MABR

No moving parts, mixing only by sophisticated fluid flow

- Low maintenance
- Low energy needs
- Modular, i.e. no scale effects
- Mobile designs possible due to container designs



High Performance Biogas Technology

Experiences which have to be improved

Tests Technical Scale



Substrates:

- Lactic acid containing waste water
- Dairy waste water
- Pig manure
- Cattle manure
- Leftovers from canteens and restaurants
- Slaughterhouse wastes

Commercial Plant Ahrenshöft



Substrate:

- Lactic acid containing wastewater

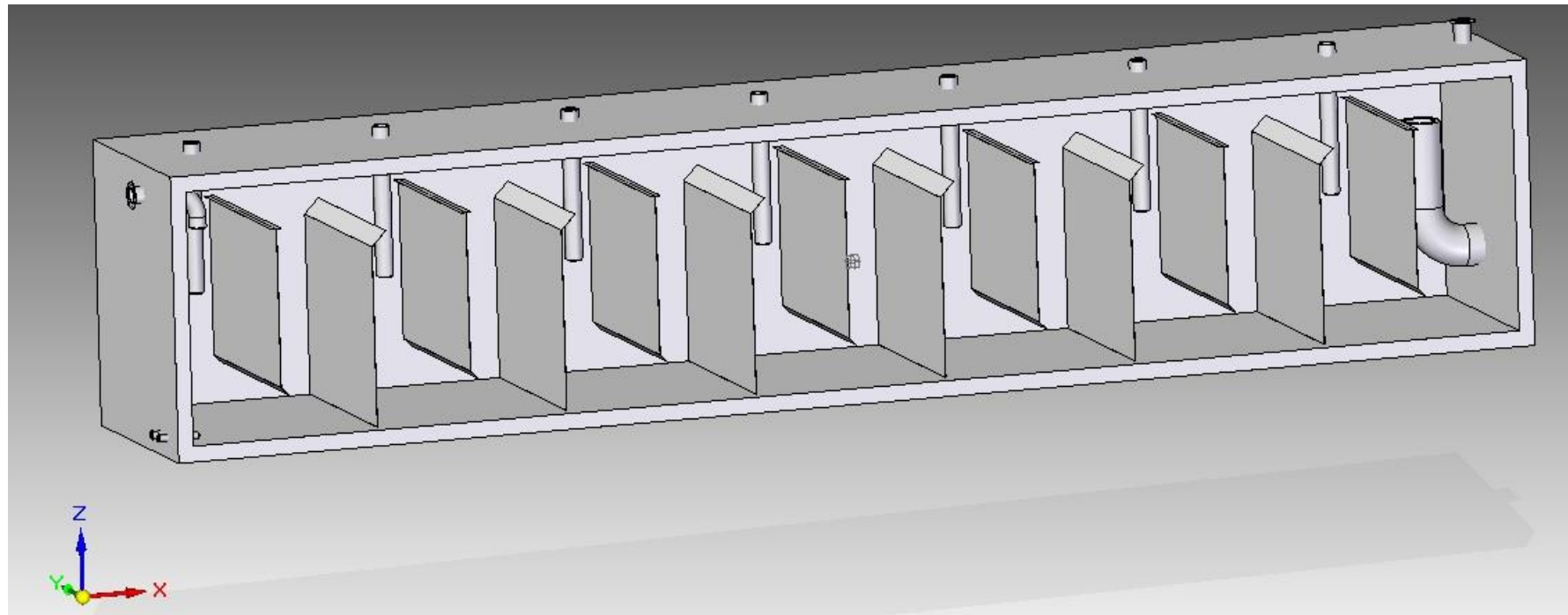
2 Patents owned by Schrader Biofermentation

Mikroorganismen in Gülle und Sickerwasser - Was geht da ab?

Some Results

Substrate	HRT [d]	Gas Yield [Nm ³ /t VS]	Gas Yield [Nm ³ /t FM]	Methane [%]
Pig manure	10	250 – 400	20 – 25	60 – 65
leftovers	12	750 – 850	120 – 130	55 – 60
Lactic acid wastewater	10	500 – 600	20 – 30	50 – 52
Sugar beet silage	8	(740 – 810)	150 – 170	50 – 52

MABR Constructions



- 2 different types of baffles constructions for pig and cattle manure
- 1 type for cleaning carbohydrate rich wastewater

Installation



Next Steps to Further Commercialisation

- 1. Improving prototypes for simple, but common applications für einfache, aber vielfach nachgefragte Anwendungen** (pig manure, carbohydrate rich wastewaters, leftovers fluidic waste streams from agro-processing)
- 2. Cheap container solutions**
- 3. Solving the ammonia problem in the outlet** (upgrading to fertiliser)
- 4. Pre treatment of less fluidic substrates** (waste, straw, residues from supermarkets)
- 5. Integrated hygienisation** (slaughterhouses, meat processing, leftovers, etc.)
- 6. Optimisation of gas upgrading**
- 7. Customer adapted solutions**

Invitation for Co-operation

CATS can offer

1. Biogas lab
2. Biogas analytics
3. ABR Technikum
4. Process optimisation
5. Life-Cycle-Analysis

- PPP F&E&O

Consulting

- Techno-Economic Feasibility
- Engineering
- Technical Consulting
- Technical preparation for new markets
- Co-operation with R&D institutions