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

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Jens Born

Flensburg University of Applied Sciences

ZNES
Zentrum für nachhaltige Energiesysteme
Universität | Fachhochschule Flensburg
Biomass

C.A.T.S.
Centrum für Angewandte Technologie
Green Process Enginnering

FH Flensburg

# 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

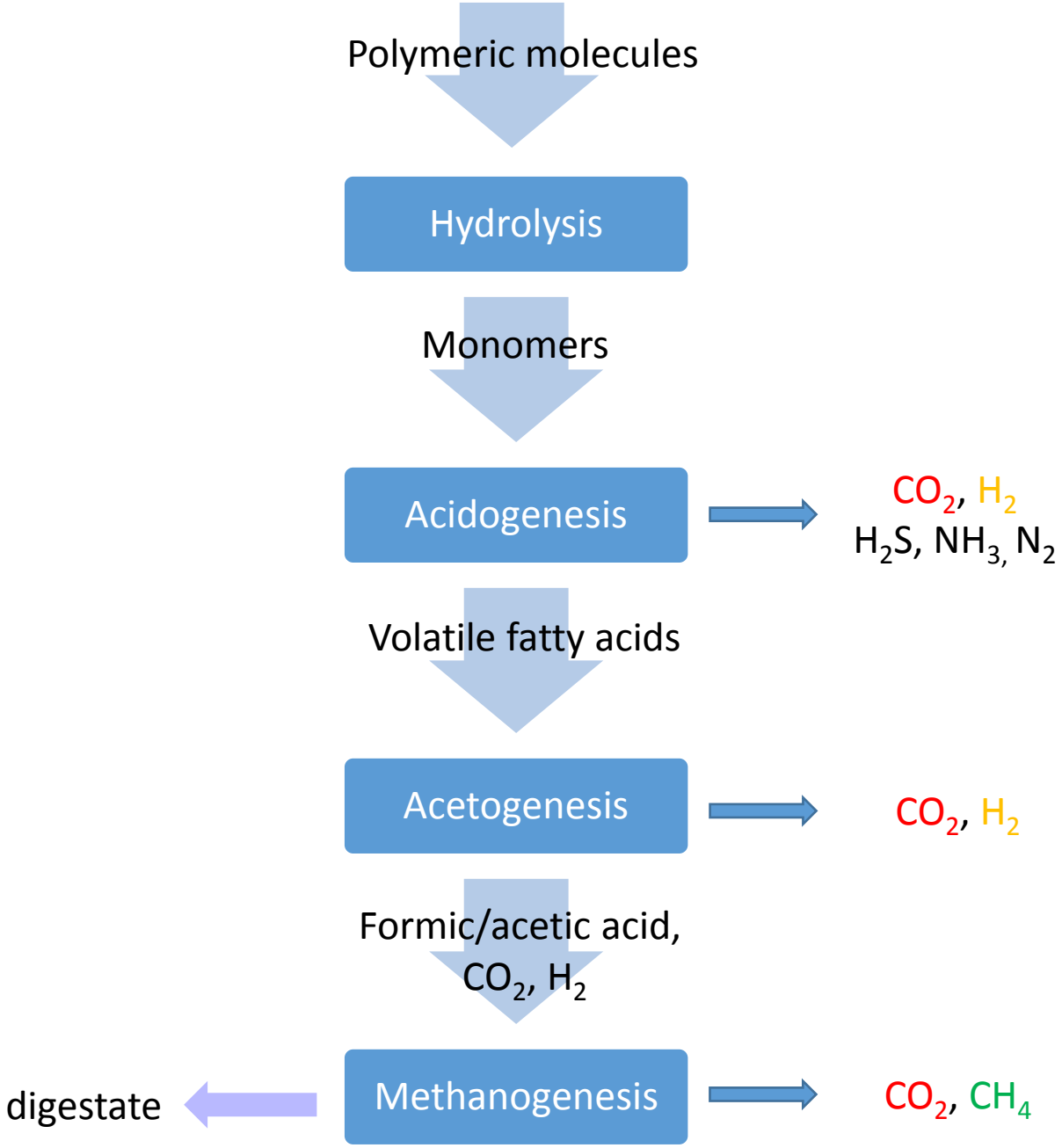
Process integration in Biorefineries
- Waste valorization in Food Industries
- Efficiency studies

Jens Born
jens.born@fh-flenburg.de
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

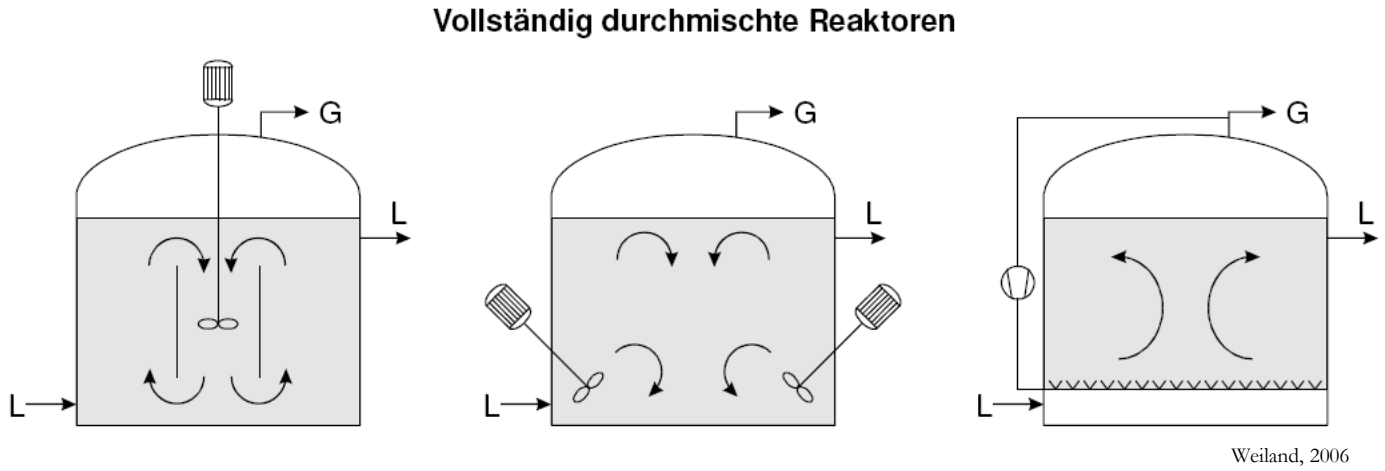


# Common Understanding of the Process Conditions of Anaerobic Digestion

| | Hydrolysis Acidification | Acetitification Methanation |
|---|---|---|
| pH-Value | 5,0 – 6,5 | 6,7 – 7,5 |
| Temperature | 25 – 35°C | 33 – 42°C (mesophil)<br>50 – 58°C (thermophil) |
| C/N-Ratio | 10 – 45 | 20 – 30 |
| Nutrients Ratios<br>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




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

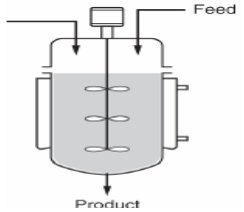
⇒ Volume and volumetric flow have to adapted to biochemical reactiond and bakterial growth rates, i.e long hydraulic retention times

⇒ conditions are equal for all mikroorganisms, 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



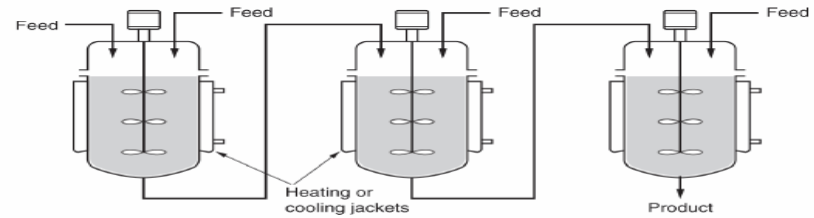




**Figure 1-2** Battery of stirred tanks. [Excerpted by special permission from *Chem. Eng.*, *63*(10), 211 (Oct. 1956). Copyright 1956 by McGraw-Hill, Inc., New York, NY 10020.]

| OLR | Feed | Biogas Yield | Spalte1 | pH |
|---|---|---|---|---|
| [kg(oDM)/(m3*d)] | [g/d] | [m3/t(oDM)] | [L(G)/(L(F)*D)] | 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 | Feed | Biogas Yield | Spalte1 | pH | Spalte2 | Spalte3 |
|---|---|---|---|---|---|---|
| [kg(oDM)/(m3*d)] | [g/d] | [m3/t(oDM)] | [L(G)/(L(F)*D)] | F1 | F2 | 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

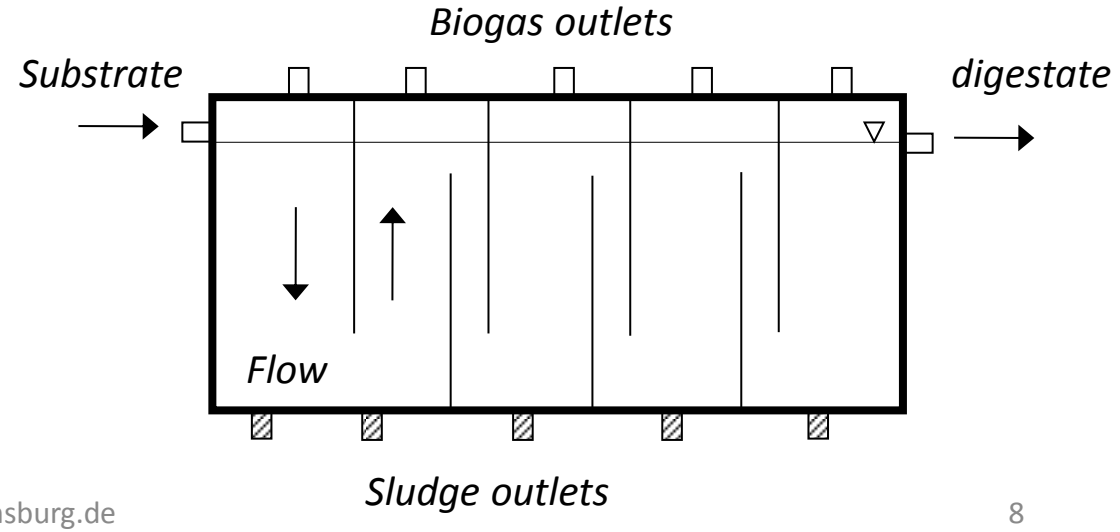
**Since several years we are developping high performance biogas technology:**

- 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

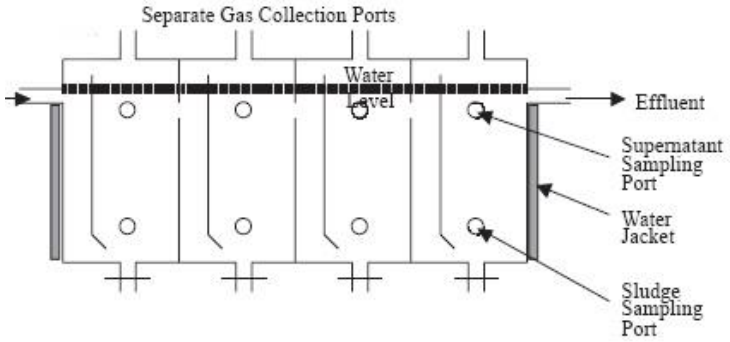
| | 1. Compartment | 2. Compartment | 3. Compartment | 4. Compartment |
|---|---|---|---|---|
| pH-Value | 4,5 – 7,0 | 5,5 – 7,2 | 6,8 – 7,3 | 7,0 – 7,3 |
| Methane | 0 – 20% | 5 – 30% | 50 – 60% | 55 – 70% |
| Carbon Dioxide | 50 – 80% | 55 – 65% | 40 – 50% | 30 – 45% |
| $H_2$-prroducing bacteria | 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

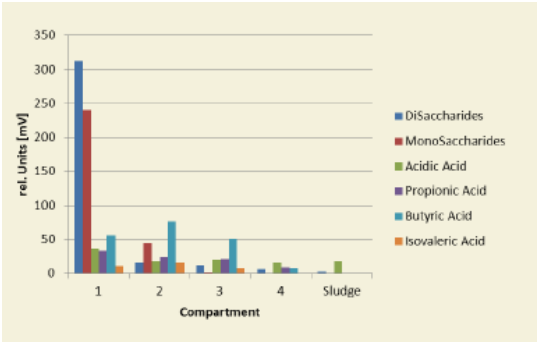
# Fermenter Technology - MABR

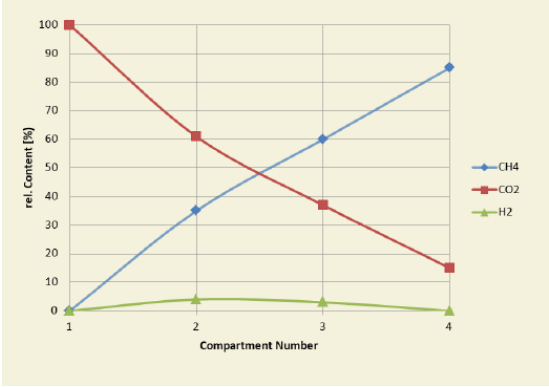
Combination of Cascades and Biofilms

- 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

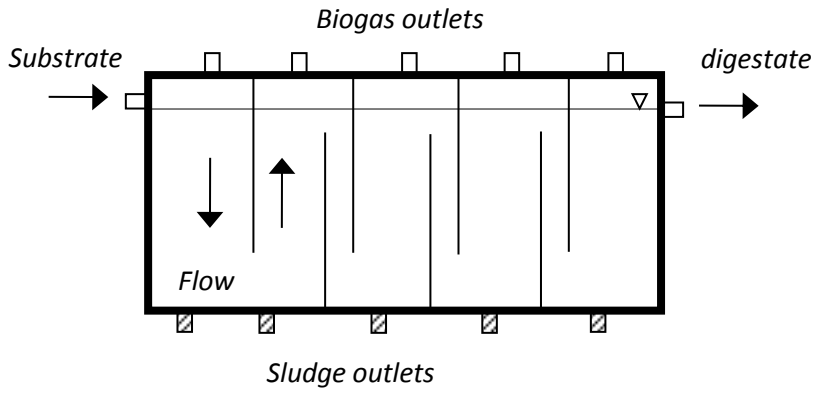
Mulit compartment fermenter with spacial separation of the complex anaerobic digestion process:

- much faster process
- Robust to shock loads
- Fixed bed fermentation
- Decoupling of HRT and SRT
- High OLR
- Reduced fermenter volumes
- Exactly controled 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 cantines and restaurants
- Slaughterhouse wastes

## Commercial Plant Ahrenshöft

**Substrate:**

- Lactic actid containing wastewater

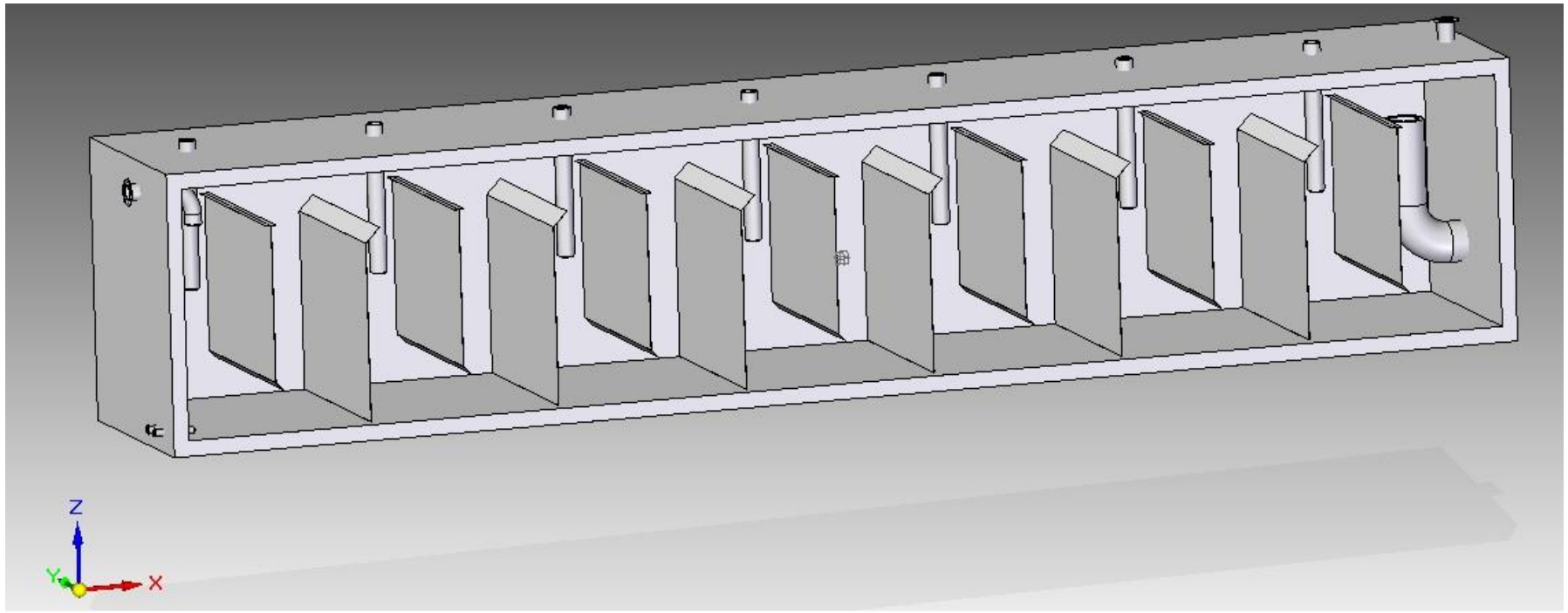
2 Patents owned by Schrader Biofermentation

**Mikroorganismen in Gülle und Sickerwasser - Was geht da ab?**

## Some Results

| Substrate | HRT [d] | Gas Yield [Nm³/t VS] | Gas Yield [Nm³/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 fludic waste streams from agro-processing)
2. **Cheap container solutions**
3. **Solving the ammonia problem in the outlet** (upgradting 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