Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

Disintegration Technologies – Impacts on Biogas Process and Profitability

Dr. Britt Schumacher, Tino Barchmann, Dr. Jan Liebetrau

IBBA-Workshop ‚Pretreatment of lignocellulosic substrates for biogas production‘

Malmö/Sweden, 10th of September 2015

DBFZ – Development, Mission, Structure

Development:

- Founded on 28th February 2008 in Berlin as gemeinnützige GmbH
- Sole shareholder: Federal Republic of Germany, represented by the Federal Ministry of Food and Agriculture (BMEL)

Mission:

The key scientific mission of the DBFZ is to provide wide-ranging support for the efficient integration of biomass as a valuable resource for sustainable energy supply based on applied scientific research.

Structure:

About 200 employees until 12/2014 in the administration and the four research departments.

General Management:

Prof. Dr. mont. Michael Nelles (scientific)
Daniel Mayer (administrative)

Fig.: DBFZ

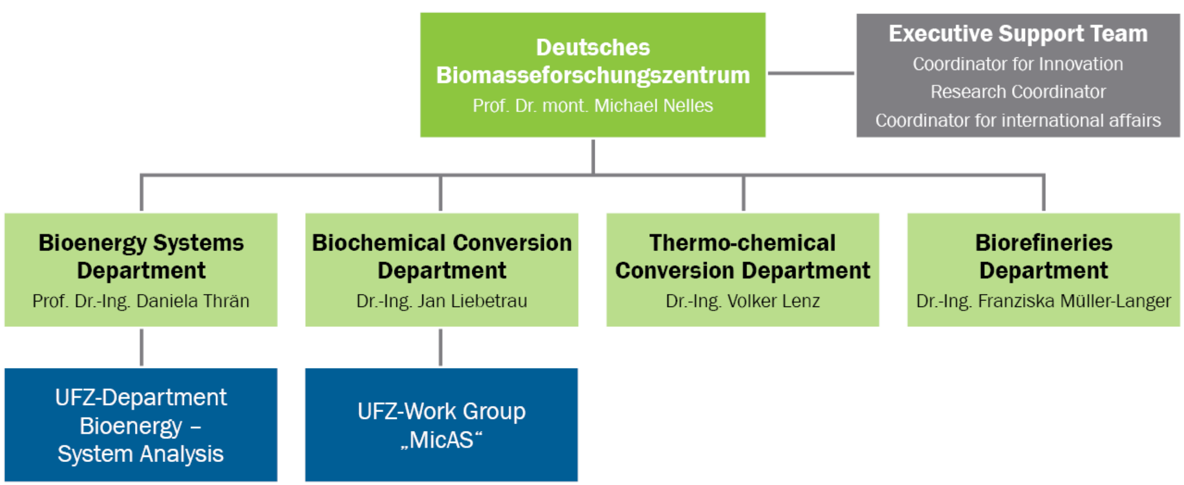
Research focus areas and structure

The four research focus areas

- Systemic contribution of biomass
- Anaerobic processes
- Processes for chemical bioenergy sources and motor fuels
- Intelligent biomass heating technologies
- Catalytic emission control

Organizational structure: the four research departments

Applied class research along the entire supply chain



Biochemical Conversion Department

Head of Department

Dr. -Ing. Jan Liebetrau
Jan.Liebetrau@dbfz.de

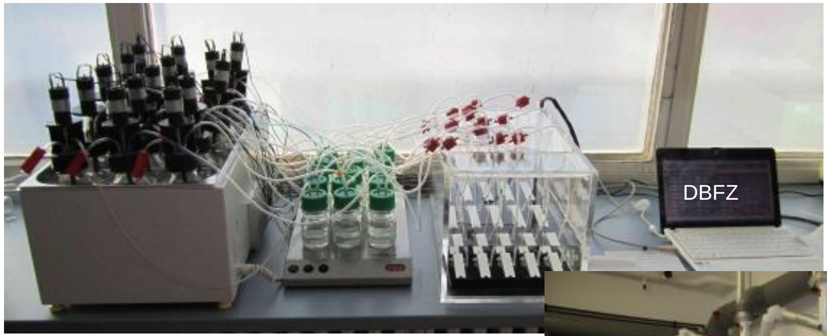
Research focus areas /working groups

- Characterization and design of anaerobic processes
- Process monitoring and simulation
- Biogas technology
- System optimization
- UFZ Working Group „MicAS“

Research services (selection)

- Discontinuous and continuous AD-Test up to full scale
- Process development for special substrates
- Consulting
- Model-based process simulations
- Acquisition of data on biogas plants in Germany
- Emission measurements and leak detection
- Ecological and economic assessment
- Policy advice for the biogas sector

Equipment – lab-/full-scale digesters



SE.Biomethane

Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages

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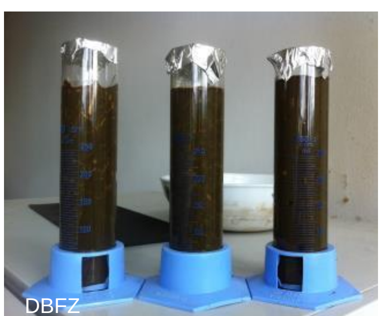
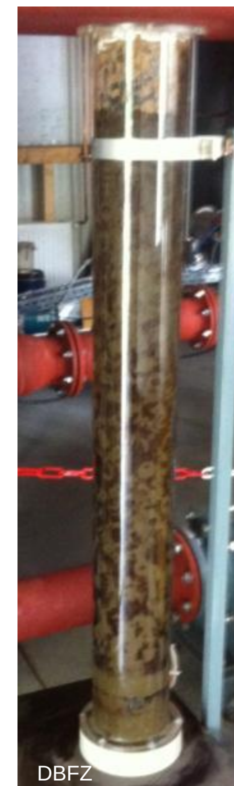
Small but efficient –Cost and Energy efficient BioMethane Production

- Supported by: German Federal Ministry of Food and Agriculture (BMEL) (FKZ 22028412)
- Partners: Ventury GmbH Energieanlagen (Germany), Poland, Sweden
- Duration: 02/2013 – 04/2016
- Focus: auto-hydrolysis, thermal-pressure-hydrolysis,
  plug flow digestion of straw, dung, gas purification





Disintegration Technologies

Disintegration – Goals & Challenges

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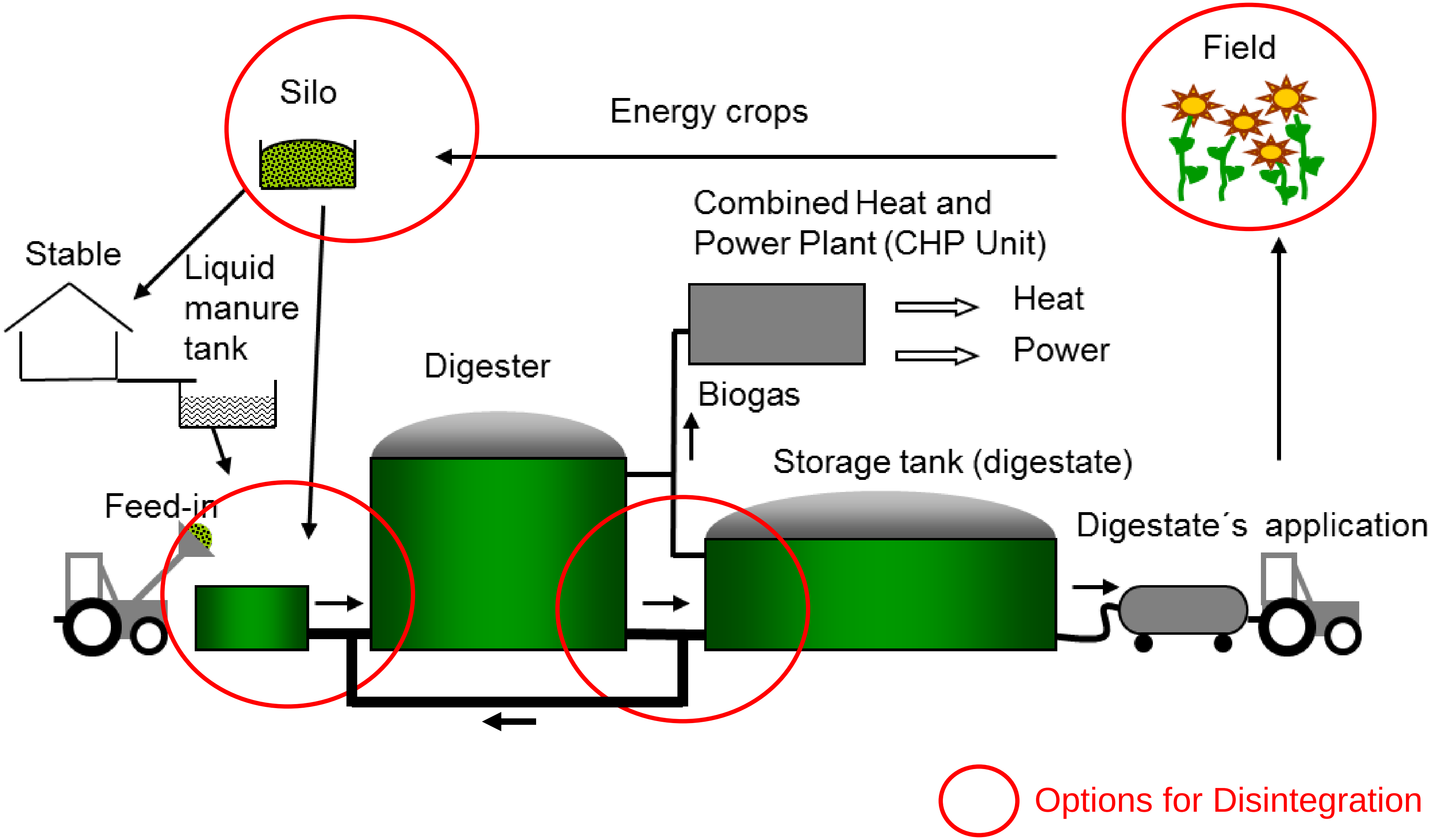
- increase of the degradation kinetics and/or biogas potential caused by disintegration of cells and reduction of the particle size
- → efficient capacity use of the digester (small plants, high loading rate)
- avoiding of floating and sinking layers
- enhancement of the management and automation of the feed-in (stirring, pumping)
- change of viscosity and change of mixing properties
- challenge for designer, manufacturer and operator of disintegration units is the proof of the efficiency changes in cost and energy under full scale conditions

Disintegration on Agricultural Biogas Plants



Disintegration – Methods´ Overview

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Physical Methods

- disintegration by size reduction or milling
- thermal treatment with hot water, steam or hydrolysis with heat and steam
- microwaves and ultrasound treatment

Chemical Methods

- utilization of acids or bases, oxidation

Biological Methods

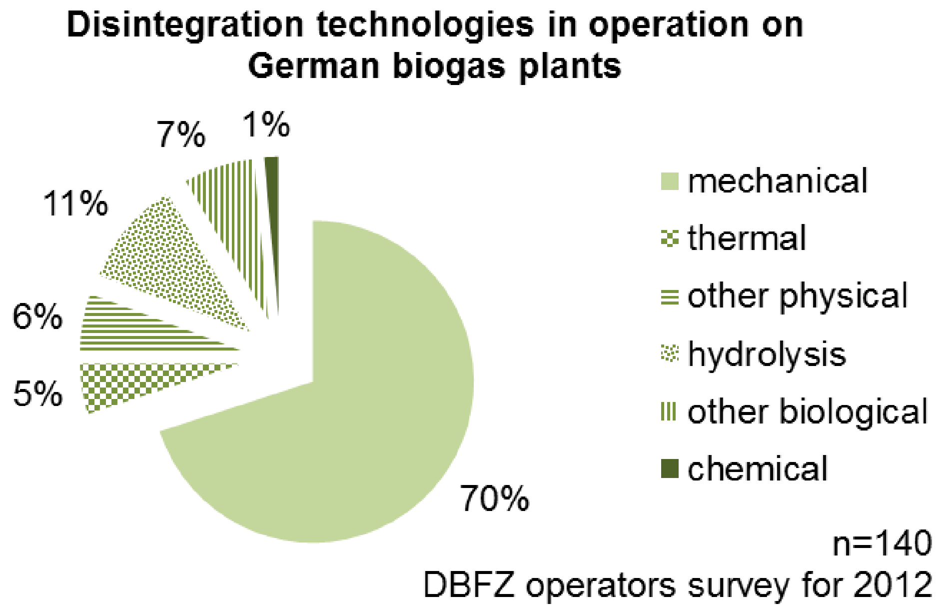
- utilization of microorganisms as additives for ensiling (substrat´s conservation) to minimize storage loss
- hydrolytic microorganisms or enzymes e.g. for substrates with high content of proteins or ligno-cellulose

Dis-/Advantages of Disintegration

- Enhanced biogas production
- Utilization of excess heat (e.g. CHP unit) is positive for energy balance
- Optionally the energy consumption of agitators and pumps can be reduced
- Additional demand on thermal or/and electrical energy
- Additional costs (investment, costs of operation)
- Additional risk of technical failure
- The risk of acidification could appear, if the feed-in frequency of pretreated substrate is too low
- Disintegration + shortened hydraulic retention time /increased organic loading rate → changes have to be made carefully and parameters of the effluent should be analyzed to avoid process failure or capacity overload
- Experiences in practice are often limited to a few biogas plants, except for macerators

Disintegration Technologies in Germany

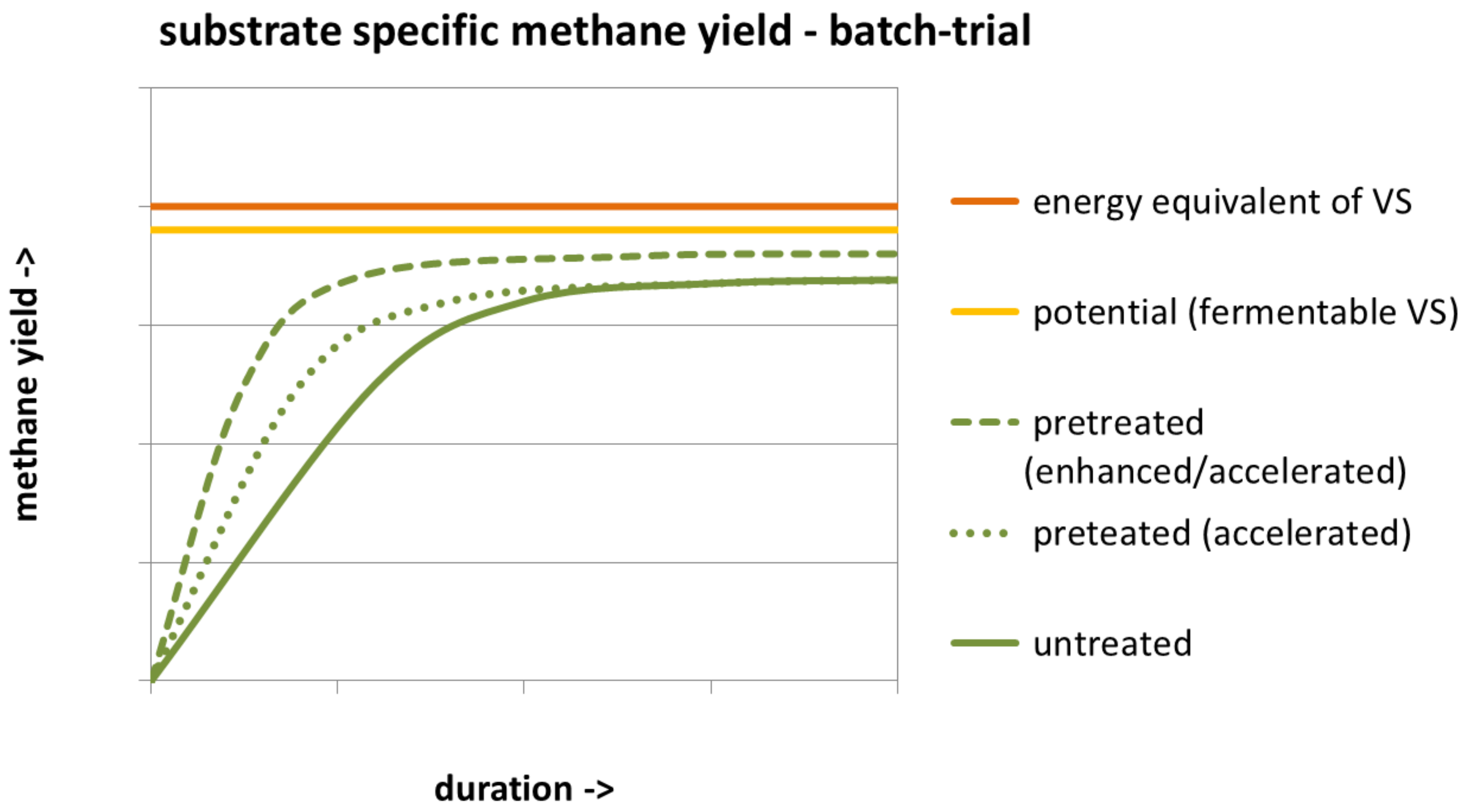
Operator´s survey – biogas sector;
DBFZ: Stromerzeugung aus Biomasse, 03MAP250, 06/2013 (data 2012)



- Appr. 7500 biogas plants were operated in Germany in 2012
- 6909 biogas plants got a questionnaire of DBFZ
- 980 operators gave a feedback
- 148 disintegration technologies were stated for 123 biogas plants

Disintegration Technologies
Impacts on Biogas Process

Discontinuous AD
Acceleration or Enhancement



acceleration is not interesting for biogas plants with long hydraulic retention time or easy degradable substrates

Continuous AD
Enhancement – losses – process failure

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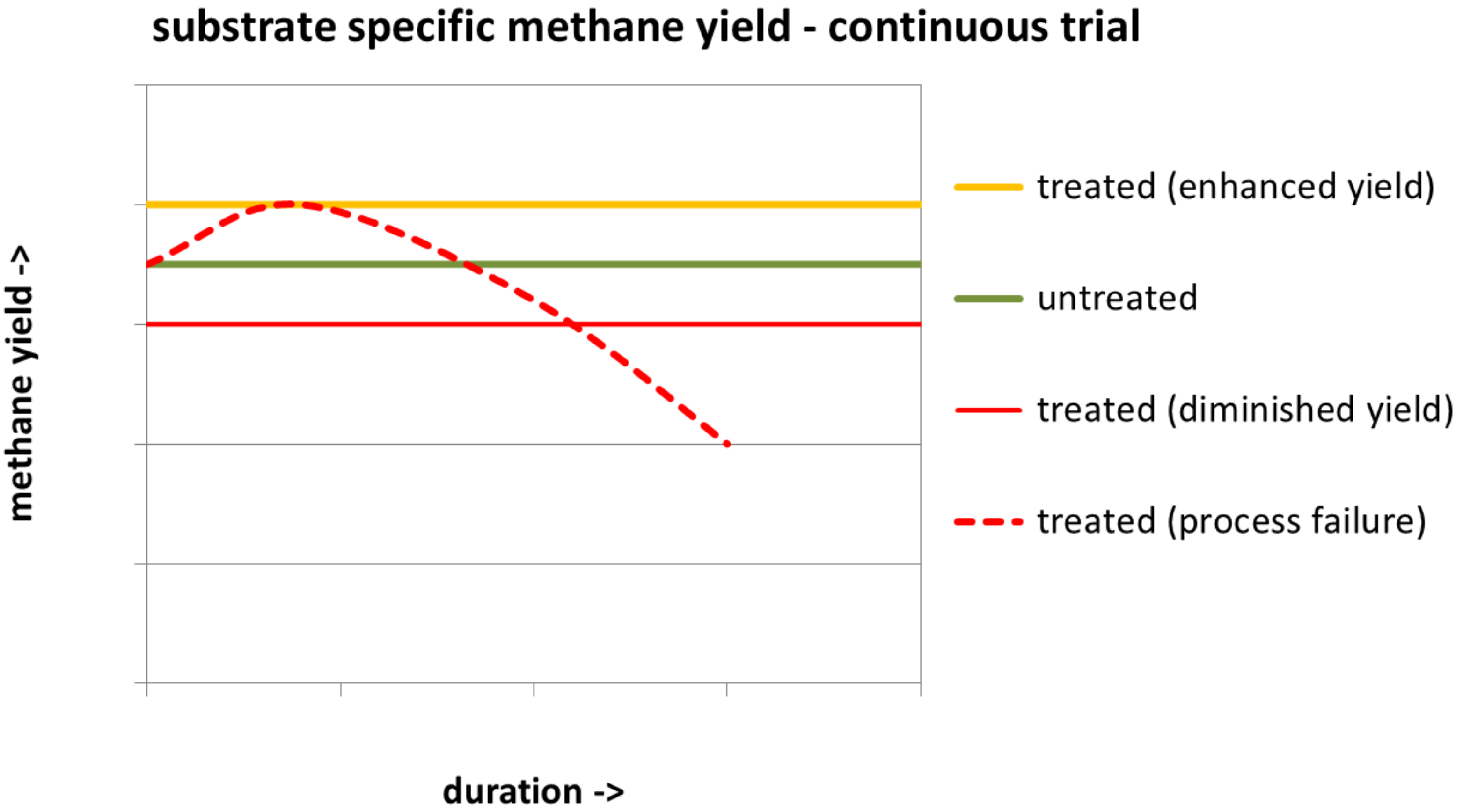

Interaction of disintegration and mixing

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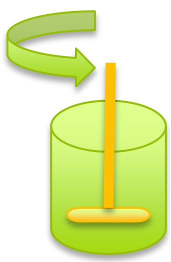
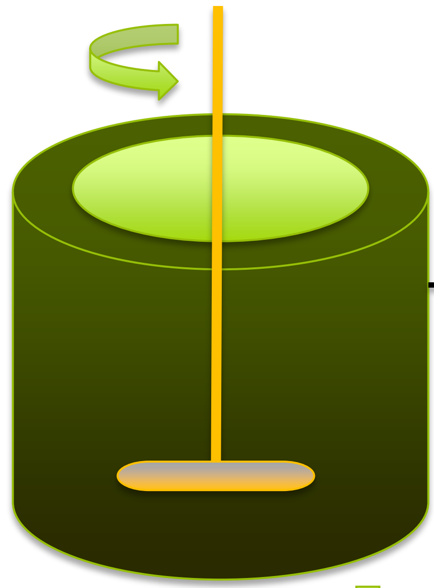
lab-scale CSTR

completely mixed



full-scale CSTR

partially mixed



dead zone
+/- 30%?

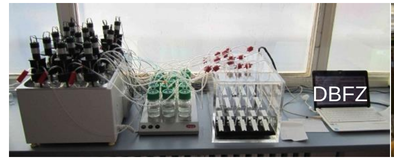
HRT ↓
OLR ↑
+/- 30%?

▲ viscosity <-> ▲volume dead zone?

Major impact of disintegration in imperfect system?

Lab experiments show limited effect?

Dis-/Advantages of different scales & tests



	Lab batch	Lab conti	Full scale
Time requirement	~ 35 d	month	month
Amount of substrate	low	medium	high
Substrate´s quality	high	high/varying	varying
Costs	low	medium	high
Parallels	easy	manageable	seldom
Process stability/ synergistic effects	no	yes, partially	yes
Rheology (Impact of mixing detectable)	no	??	yes
Lack of nutrients/ inhibition detectable	no	yes	yes
Mono-fermentation	no	yes	yes
...changes in gas yield are detectable	small	small/medium	large
Relevance of results?	low	medium	high

Conclusion – Impacts on Biogas Process

- Two effects of disintegration: acceleration and/or enhancement of the conversion of substrate
- Losses or process failure are also possible
- The effects are dependent on the composition of the substrate and the disintegration method
- Acceleration is not interesting for biogas plants with long hydraulic retention time or easy degradable substrates, because non-treated substrates might reach the same degree of degradation
- Acceleration might be interesting for biogas plants with short hydraulic retention time or hardly degradable substrates and/or the wish of capacity expansion
- A real enhancement of the biogas yield is hardly to achieve
- Due to varying mixing, lab- and full-scale trials might show different results

Disintegration Technologies
Impacts on Profitability

Overview: Cost Structure – Biogas Plants

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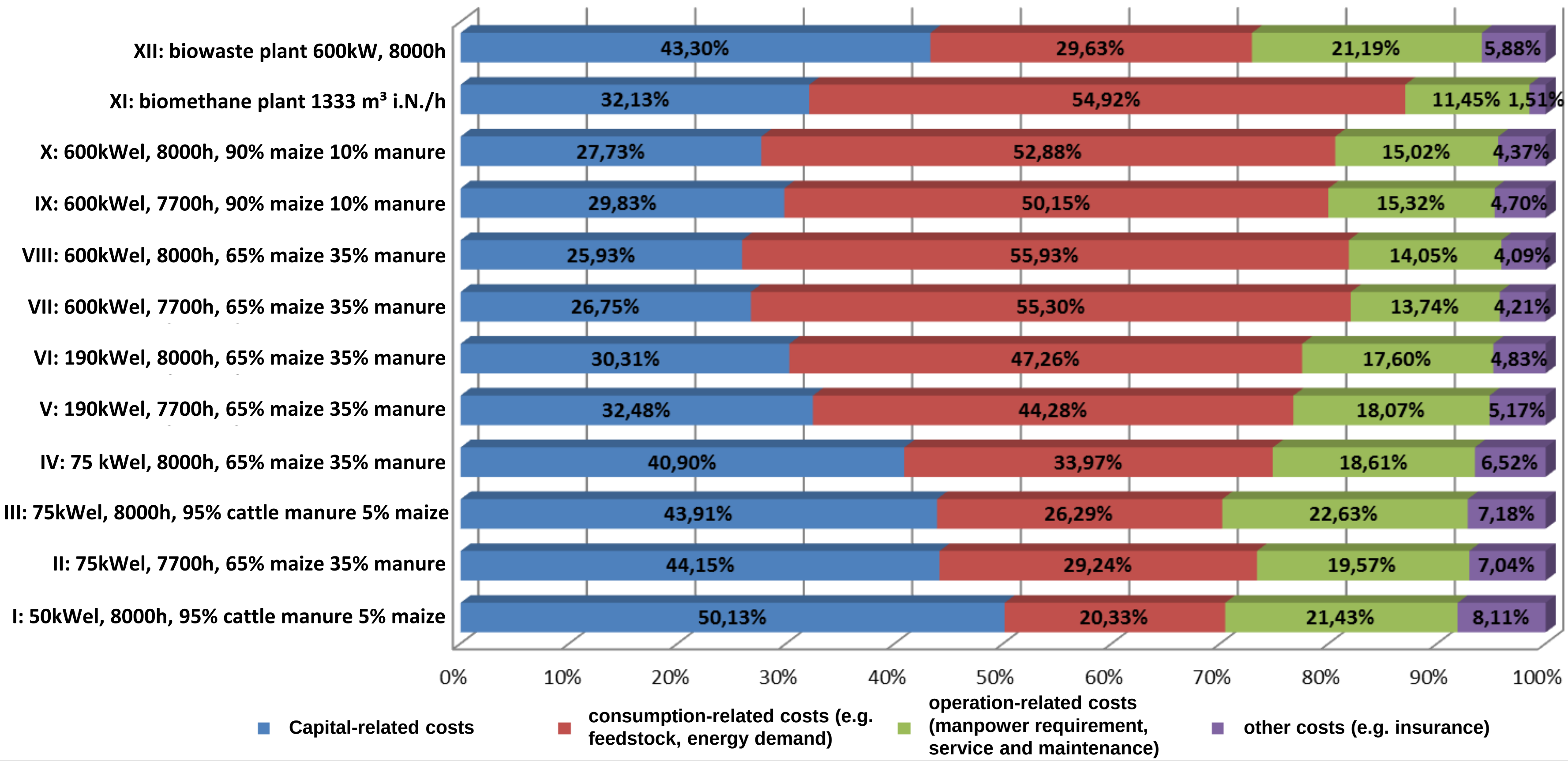
Various samples for German biogas plants



Source: M. Trommler (2011), Nachhaltige Biogaserzeugung in Deutschland – Bewertung der Wirkungen des EEG, Endbericht, Förderkennzeichen 10NR034.

Investment for Disintegration Technologies (D)

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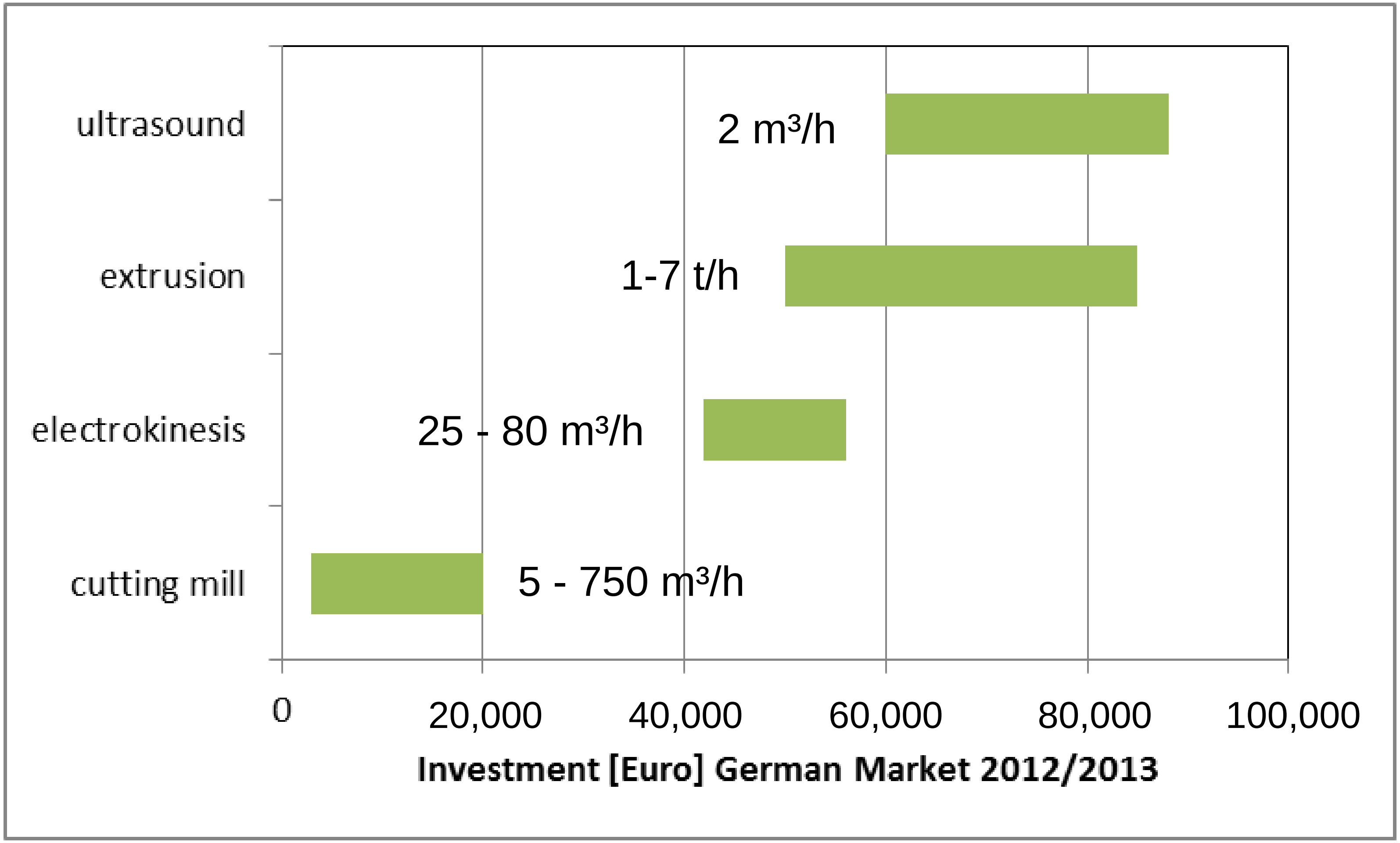
Investment depends on the manufacturer and the throughput (m³/h or t/h)



Exemplary calculation - assumptions

1. 500kWel CSTR, new constructed biogas plant (01.01.2016)
2. Calculation of production costs of electricity/investment calculation (annuity method VDI 2067)
3. Invest cutting mill: 2*15,000€ = 30,000€
4. Invest thermal-pressure-hydrolysis (TPH): 500,000€
5. Lightweight construction depot for straw: 200,000€
6. Costs cattle manure: 0€/t FM
7. Costs straw: 80€/t; 100€/t; 120€/t FM
8. Revenue of surplus heat from CHP: 3 €ct/kWh th
9. Utilization of rejected heat of CHP for TPH, rise in heat demand for the whole biogas plant from 20% to 40% for TPH.
10. Marketing of surplus heat: 50%

Exemplary calculation - assumptions

11. Gas yield cattle manure (KTBL): 16.8 m^2 CH4 N/t FM
12. Gas yield straw (KTBL) cutting mill: 162.54 m^2 CH4/t FM
13. Gas yield straw TPH: 180.42 m^2 CH4/t FM (enhancement compared to cutting mill: 11% (Schumacher et al.))
14. Mix of substrate (fresh matter related): 7% straw, 93% cattle manure

VDI 2067: Economic efficiency of building installations – fundamentals and economic calculation, Beuth Verlag, Sept. 2000

KTBL: Faustzahlen Biogas, 2013

Schumacher et al.: Disintegration in the biogas sector – Technologies and effects, In: Bioresource Technology. Bd. 168, p. 5, 2014

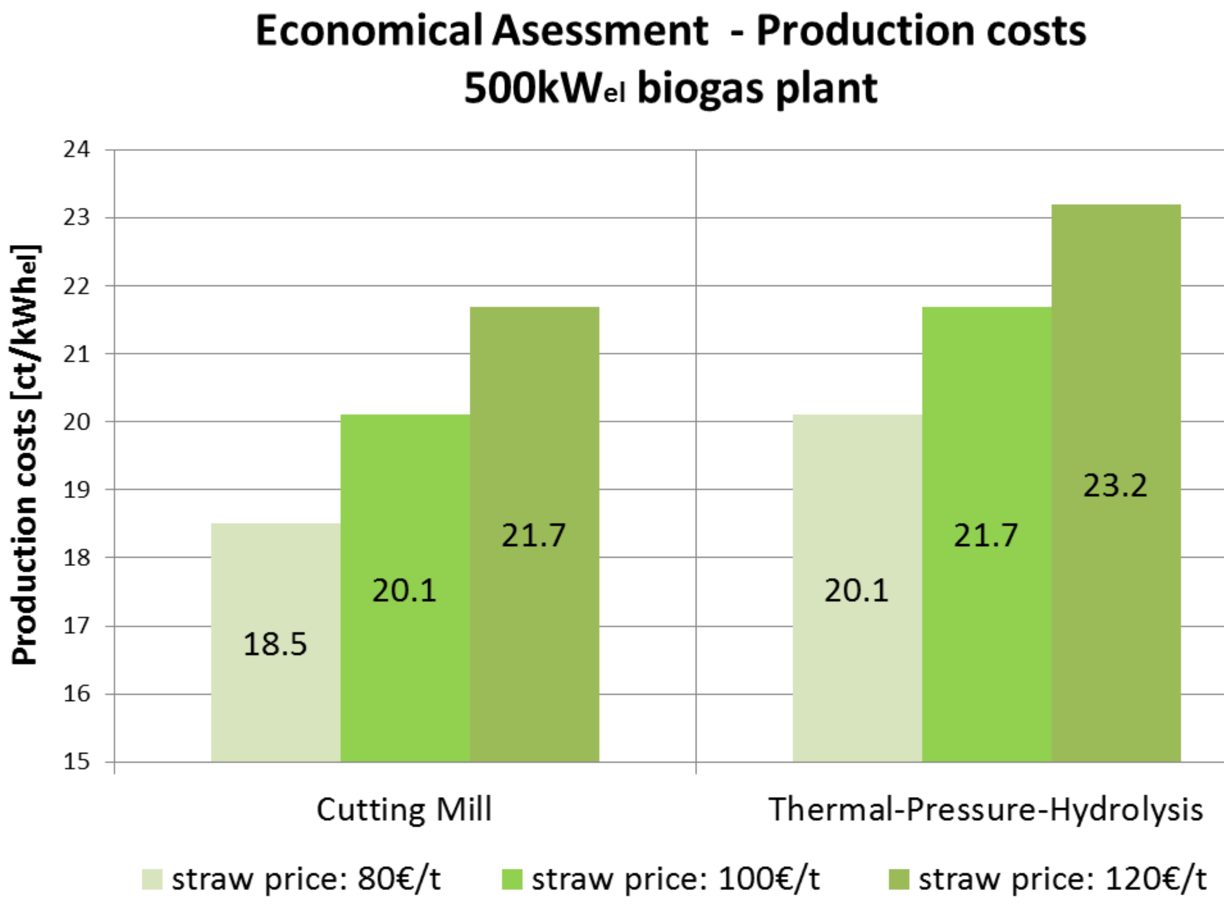
CSTR – continuous stirred tank reactor

CHP – combined heat and power plant

FM – fresh matter

th- thermal

Exemplary calculation



Conclusion – Impacts on profitability

- Mechanical pre-treatment is State-of-the-Art, but energy demand as well as operational costs are dependent on the substrate and should be reduced
- High expectations in Thermal-Pressure-Hydrolysis (TPH) etc., but the high energy demand, high invest and technical design are challenging

Conclusion

- disintegration: can lead to accelerated and/or enhanced conversion of substrate or losses of substrate
- case-by-case calculations have to be made for every biogas plant, to reveal the limits of profitability
- variables are e.g.:
  - composition of substrate/substrate´s mixture,
  - substrate´s costs (logistics),
  - available treatment units (e.g. invest, its energy consumption, wear and tear),
  - reactor design (including mixing),
  - hydraulic retention time,
  - usage of digestate (logistics) etc…

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Thank you for your attention!

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