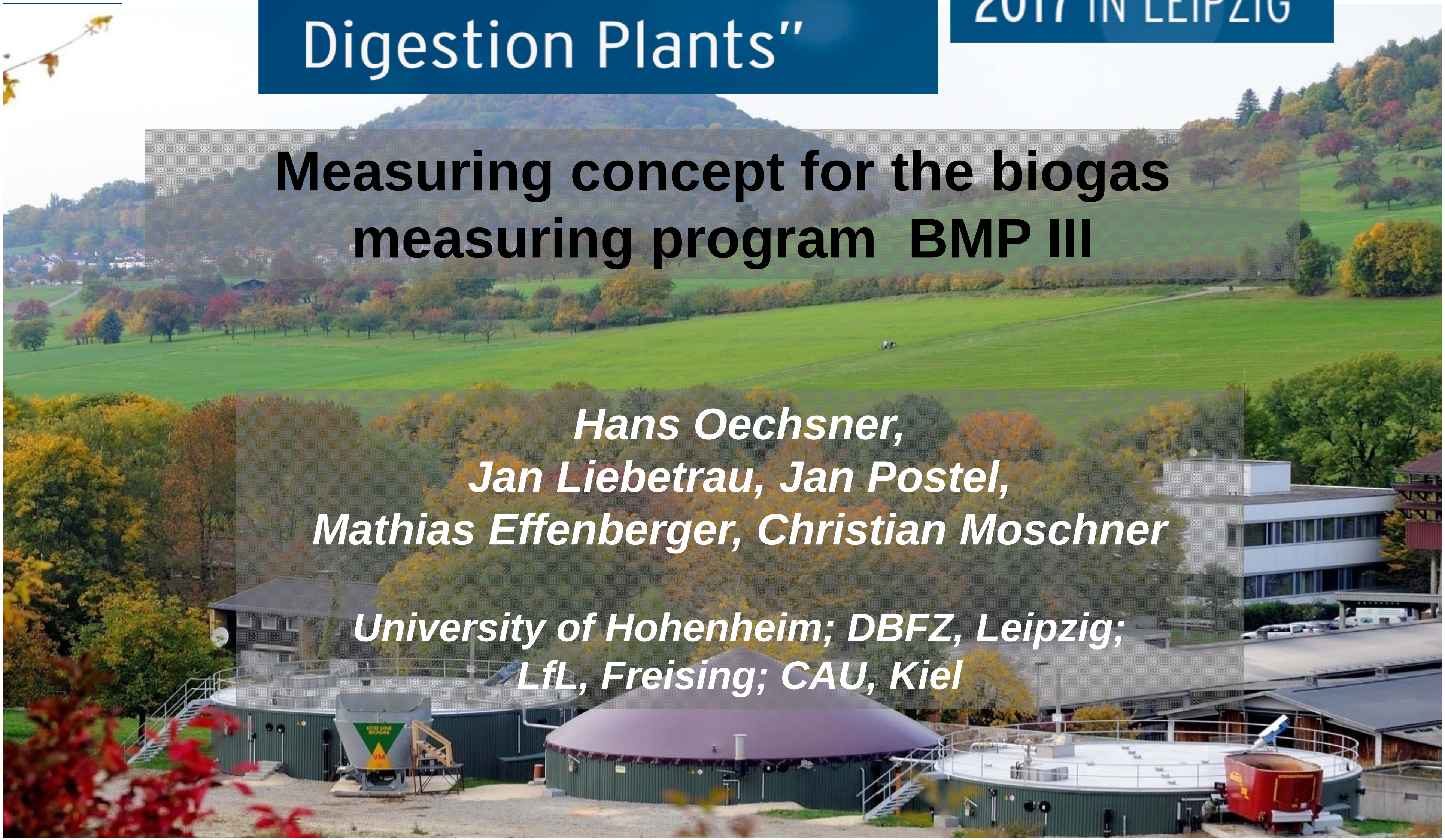
III. Conference on
"Monitoring & Process Control of Anaerobic Digestion Plants"

MARCH 29 — 30
2017 IN LEIPZIG

LANDESANSTALT
für Agrartechnik
& Bioenergie



Measuring concept for the biogas measuring program BMP III

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Measuring concept for the biogas measuring program (BMP III)

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- Introduction
- BMP III – Program
  - Cross-sectional topics in BMP III
- Biomethane potential test – guidelines - restrictions – reliability
  - Round robin tests for evaluation of quality of own results
- Transformation from batch to continuous examination
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- Conclusions

Previous German Biogas Measuring Programs - BMPs

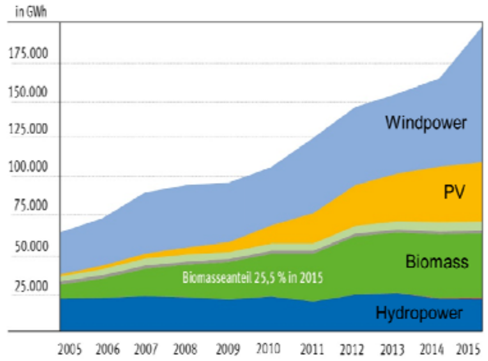
- **BMP I** (2001 – 2004)
  - Selection of plants based on technological and material aspects
  - Use of organic waste, manure or energy crops

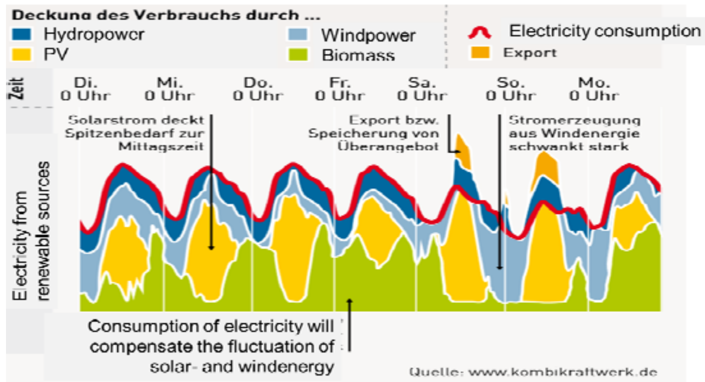
- **BMP II** (2005 – 2008)
  - Use of energy crops (manure free plants)
  - Efficient use of exhaust heat
  - Solid (dry-) fermentation

- **Handbooks** with detailed information, available at FNR

Problem and Aim of the BMP III

- Increasing share of renewable energy (33 % of consumed electricity)
- New challenges
  - Better efficiency in production and use
  - Flexibility and repowering
- State of the art for existing and innovative technologies
- Knowledge transfer to policy, practise and consulting





Evaluation of 60 biogas plants for a period of 1 year each by 4 partner institutes

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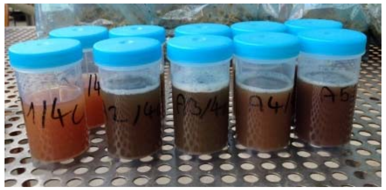
- Plants with innovative heat usage concepts
- Demand driven production of electricity
- Pretreatment of sustrate
- Treatment of digestate
- Small farm biogas plants
- Energetic efficient plants
- Plants with repowering
- Flexible driven plants

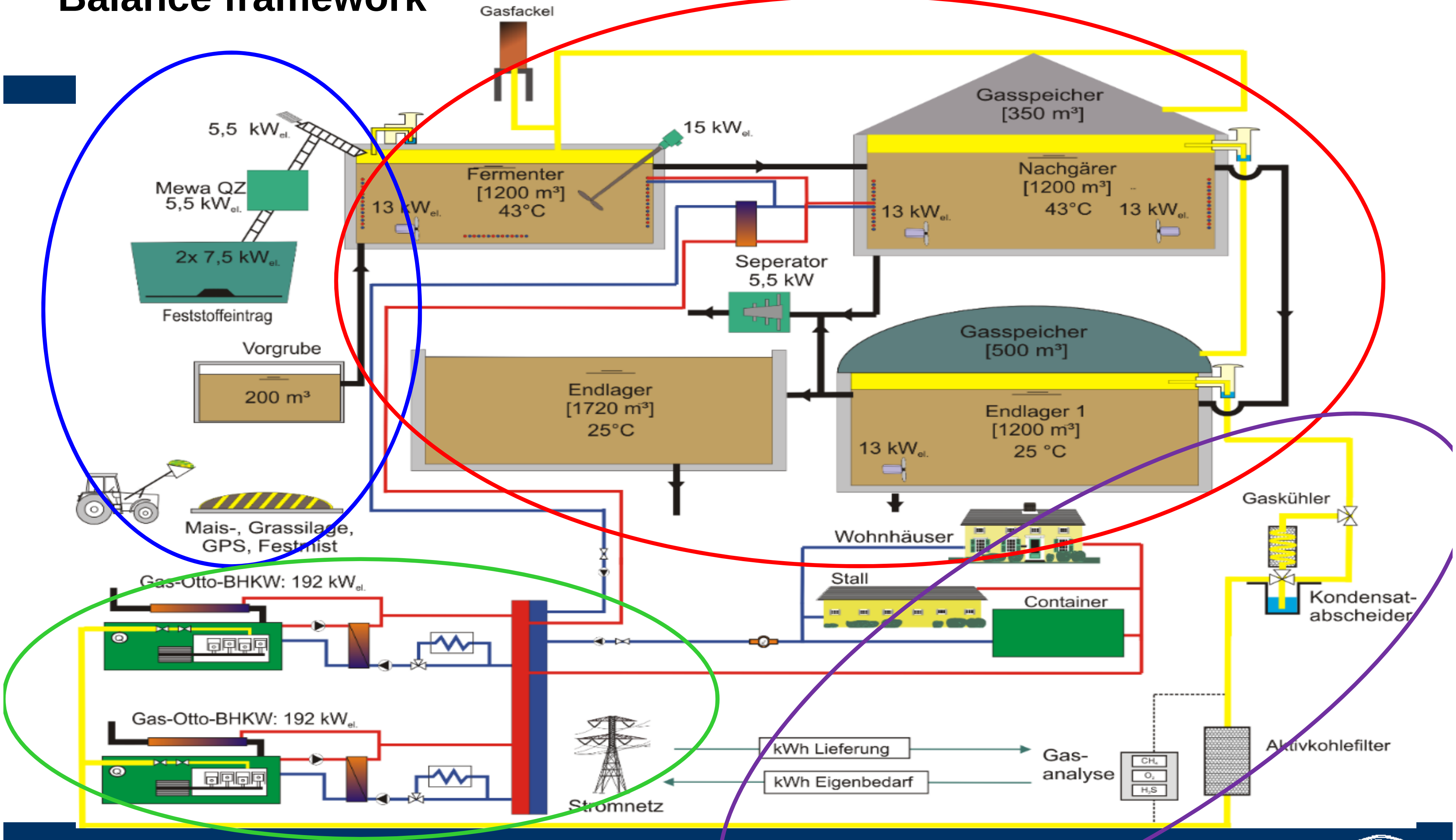
Provision of BMP III

- Data collection (monthly)
- Sample analysing
  - Chemical parameters; pH, VFA, alcohols, FOS/TAC, FoTS, fiber content, heating value, …
  - Methane yield of substrates
- Balancing of input- and output-streams
- Energy production and consumption (electricity and heat)
- Environmental aspects of plants (residual methane potential)
- Economy of plants



German Biogas Measuring Programs BMP´s

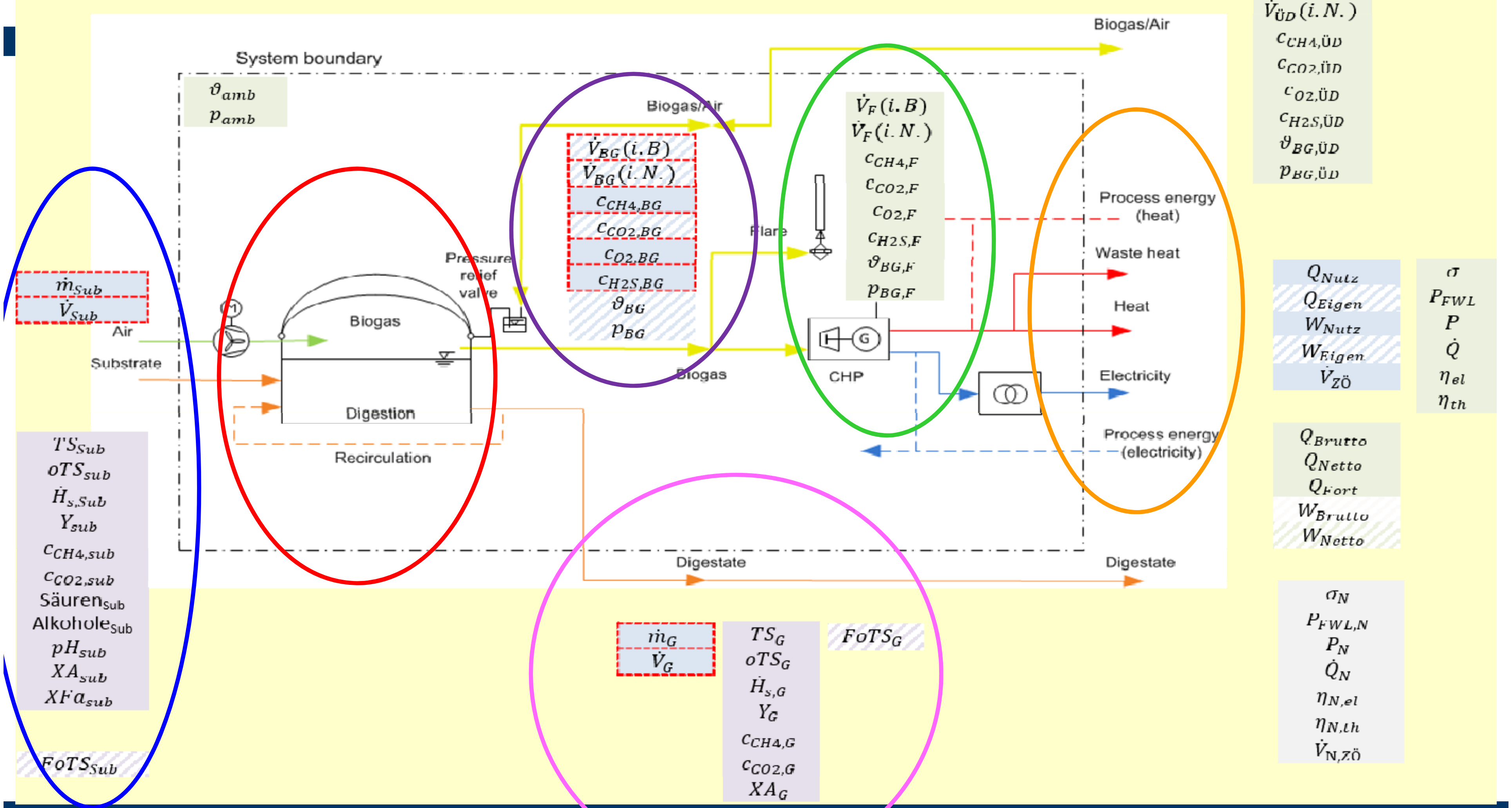
Balance framework



Overview - veracity and availability of data

Liebetrau, Postel, 2017

available
Partly available verfügbar
Seldom available
Not available
Lab analysis
No Standard lab analysis
Basic claims data
Veracity questionable



Cross-sectional topics in BMP III for the working groups

- Evaluation of repowering steps (Effenberger, et al.)
- Energy balance, flexibilisation (Liebetrau, Postel, et al.)
- New methods for process evaluation – heating value – chemometric analysis of titration curve – infrared spectroscopy (Moschner et al.)
- Economical evaluation (Liebetrau et al.)
- Efficiency of biological process – methane yield and residual methane potential - round robin tests for squaring BMY-results (Hülsemann, Nägele, Oechsner)

Wherefore do we need BMY-Tests?

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- Economy of biogas plants is deteremined by the costs of substrates
- Quality of used substrates is variing
- Content of Carbohydrate, Protein and Fat correlates with the Energy content and the quality of biogas
- Composition of CH-Fraction is crucial influencing the digestibility
- Analytical prediction is because of complex composition of subtrates difficult

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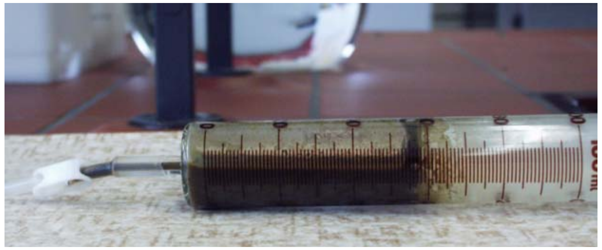
Guidelines for BMP-Tests

- DIN 38 414, relevant for analysing of sewage sludge
- VDI-guideline 4630 defines proceeding (2006, 2016)
- Adapted for DM-rhich digestate
- VDLUFA-Method description (2011)
- European standardization of biomethane potential tests (Holliger et al., 2016)
- Quality of laboratory tests has to be prooved

Minimum of test conditions (I)



- Use of suitable, gas tight and temperated **laboratory digester**
- Use of **well running Inoculum** (high buffer capacity, low gas production of inoculum)
- **Mixing relation** of Inoculum : testing substrate in relation of VS: > 2 : 1
- Inoculum parallel as control
- At least one **standard substrate** (f.e. micro-cristalline Zellulose), for a control of the inoculum
- Digester temperature mainly 37°C ± 2°C

Minimum of test conditions (II)

- **3 Replications** each substrate
- Analysing the biogas yield as as possible
- For each sampling of gas volume, the **gasquality** is relevant
- At least 25 days of digestion, better **35 days**
- Cancellation point: < 0,5 % of the previous gasvolume at minimum 3 days

Minimum of test conditions (III)

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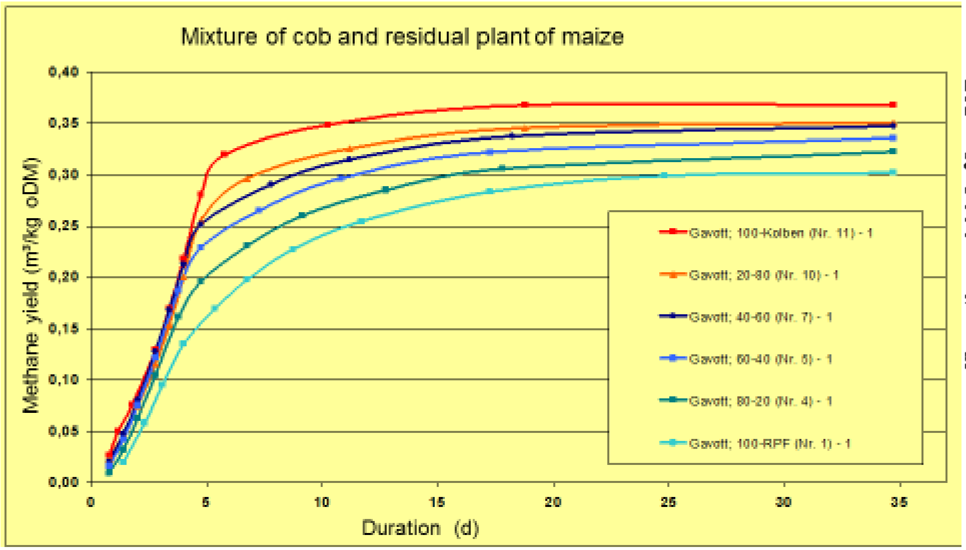
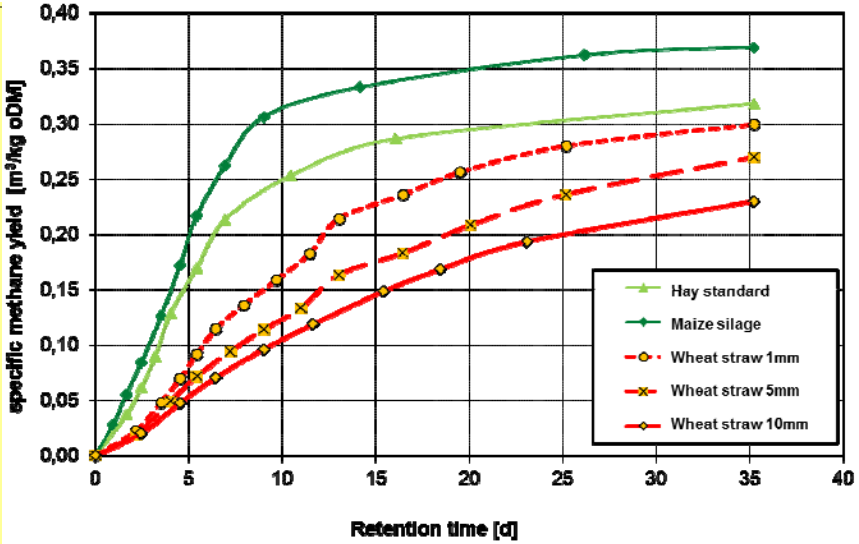
- Comparison of the methane yield per kg VS-input
- Correcting of the VS-value for the value of VFA
- Norming of the gas yield (0°C, 1013 hPa)
- Watersteam in gas has to be removed





Reference material - standard

- Control of the digestion process by a well known substrate
- microcrystalline cellulose, maybe supplemented by an additional in-house reference sample.
- Cellulose:
  - Gas output of **745 ±10 % l_N per kg oDM** must be maintained
  - Methane output **375 ± 10% l_N per kg oDM**

Method: residual methane potential

- To gather a representative sample from the overflow of the last gas tight digester
- Digester cascades can be probed (analyse the influence of HRT on degredation rate)
- Analysing of: DM-, oDM-content, pH-value, VFA
- Inkubation of 3 replications (without inokulum addition)
- Two digestion temperatures are used
  - Mesophilic range: 37 ± 1°C (residual methane potential)
  - Psychrophilic range: 20 ± 1°C (methane emission potential)
- Duration of incubation: 60 d

Residual methane potential – evaluation

- **Specific methane yield per kg VS** in the digestate will be calculated

  [Nl methane / kg VS in the digestate sample]

  standardized: 1013 hPa, 273,15 K

- Reference to real gas production of the investigated biogas plant

  [% **residual methane potential, RMP**]

  Necessary, to get measured data from the observed biogas plant

$$RMP = \frac{V_{RG}}{V_{BGP}} * 100 \quad [\%]$$

RMP residual methane potential

V_{RG} volume of residual gas analysis

V_{BGA} volume of methane of the plant

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Round robin test for protection of the research quality

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- Round robin tests at KTBL together with VDLUFA-NIRS GmbH since 2006
- 2006 (17 Labore), 2016 (30 Labore)
- Intensive error analysis and discussion of the participants to improve the quality of results
- New european Test started in 2016

Round robin test with microcristalline cellulose

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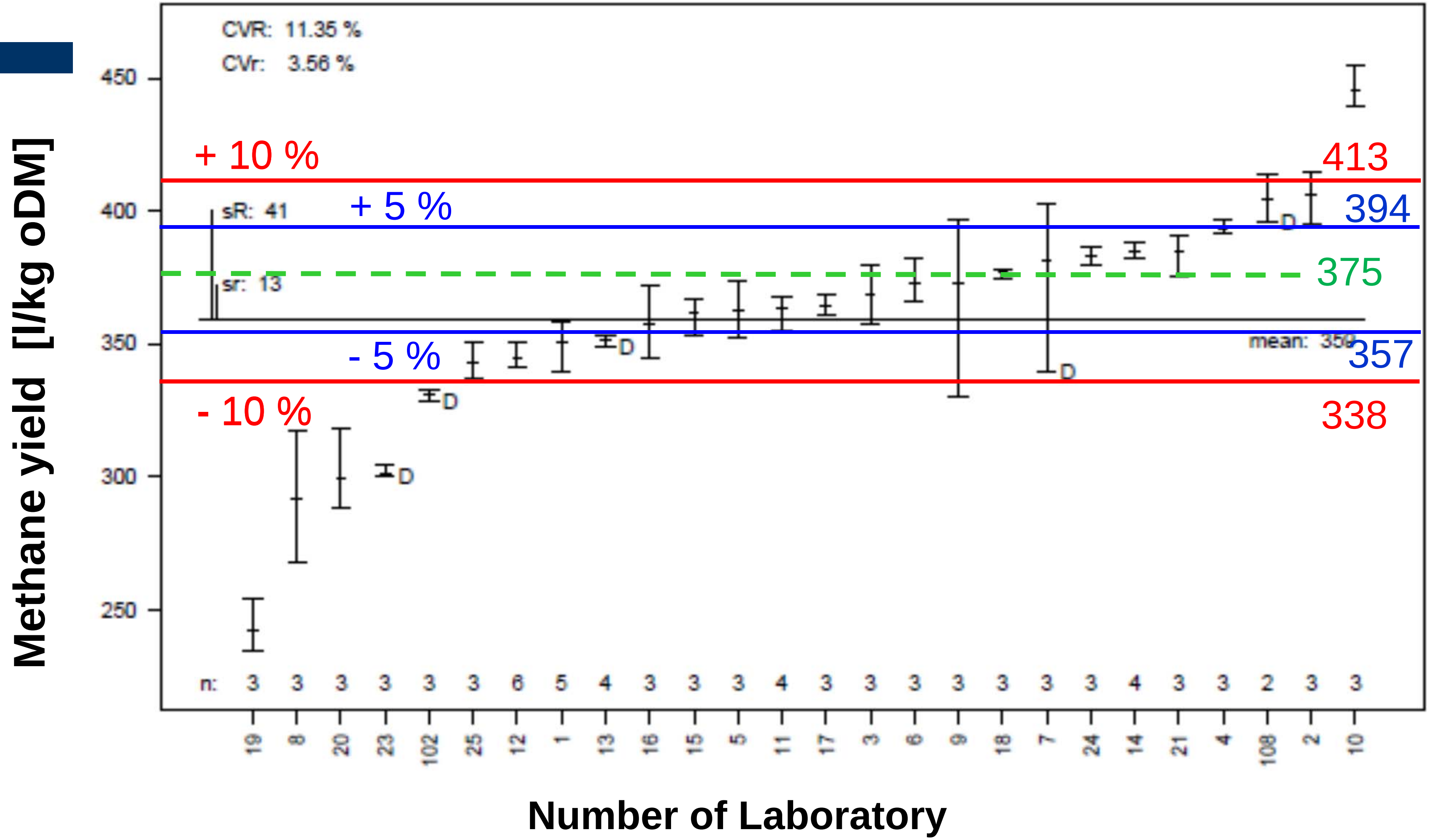
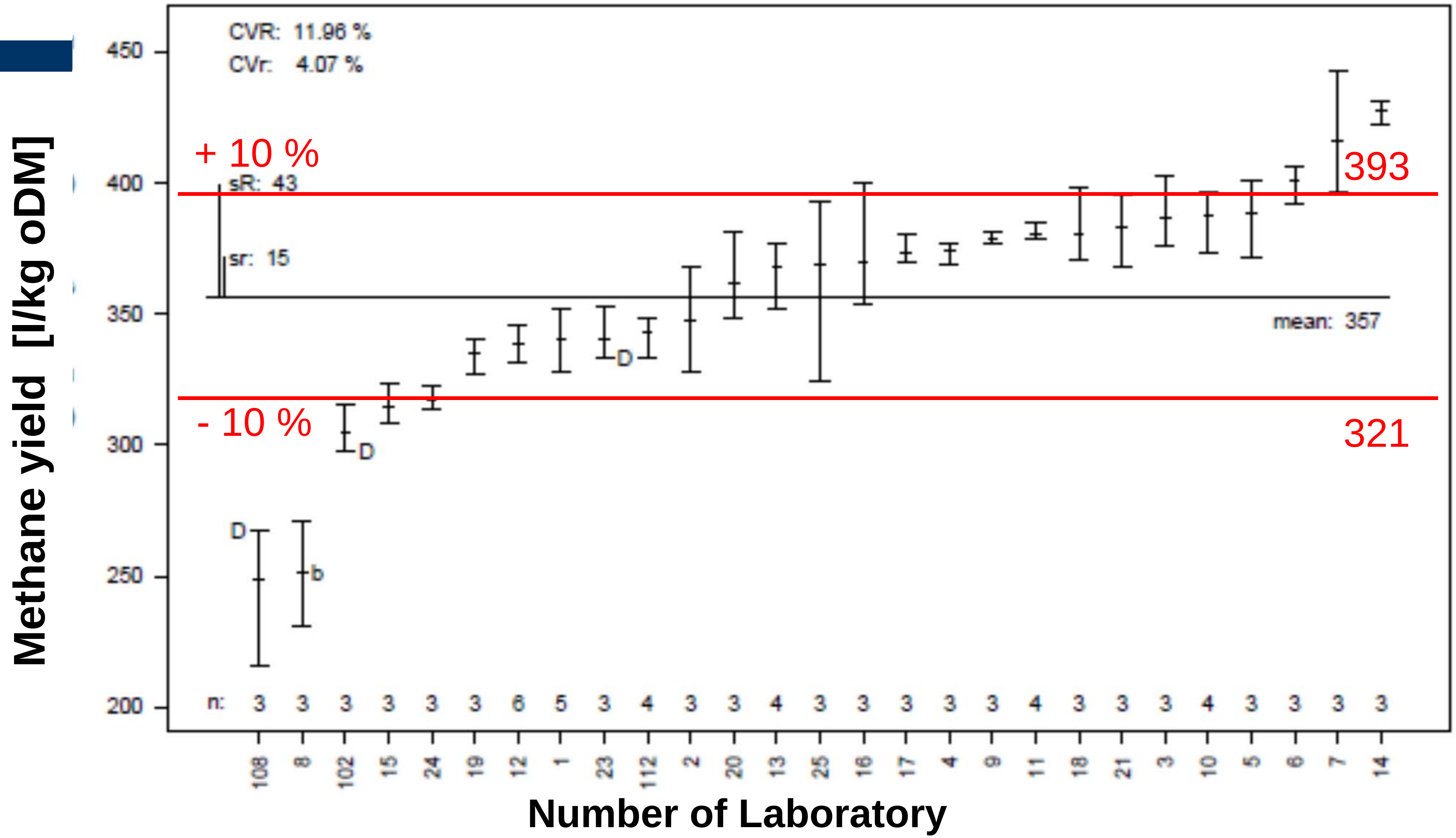


Round robin test with maize silage



Improved quality of Round robin test results over the time

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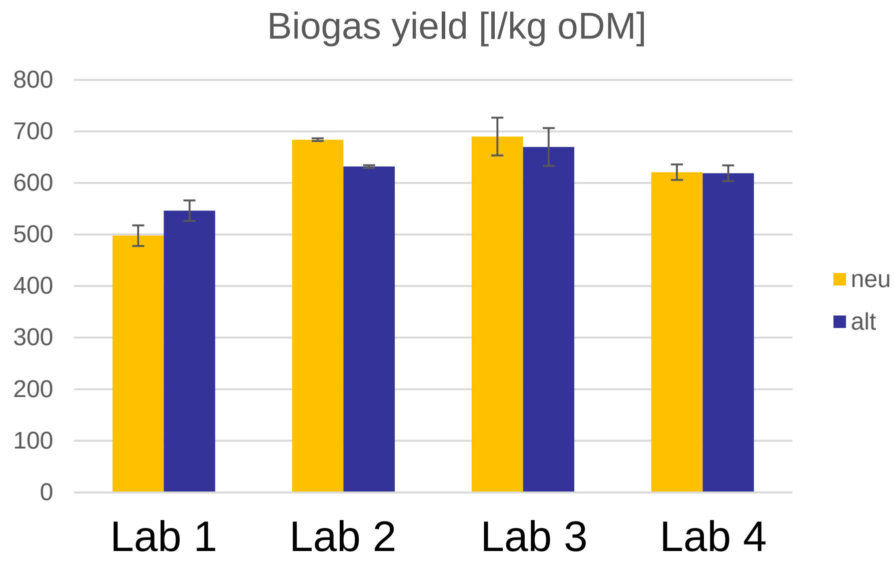
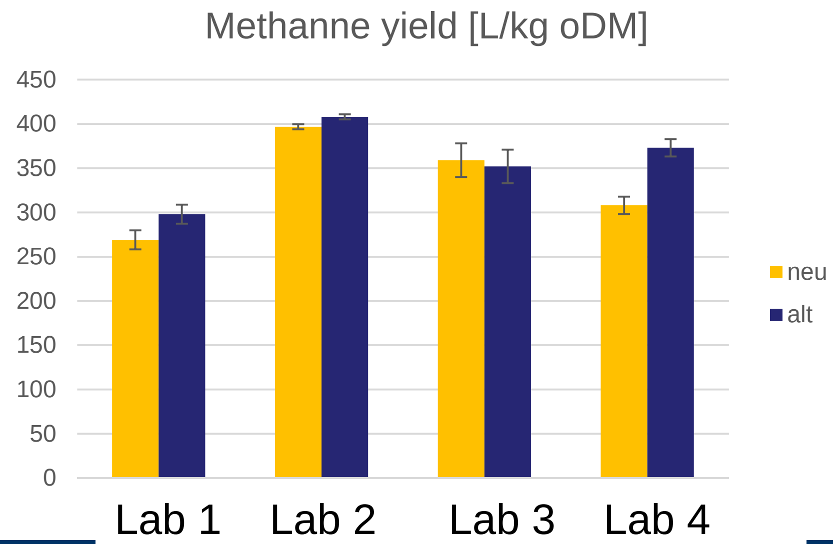
Cellulose	2006	2007	2008	2011	2013	2014	2015
Nr. laboratories	16	19	27	31	28	28	24
Gas yield [m³/kg oDM]	742	724	700	736	729	728	725
CV_r	2,9%	3,4%	4,3%	3,0%	2,2%	1,9%	2,2%
CV_R	17,0%	10,0%	8,0%	4,5%	4,9%	4,5%	6,1%
Methane yield [m³/kg oDM]	386	358	358	373	369	359	358
CV_r	3,8%	4,2%	4,9%	3,5%	2,4%	2,8%	3,1%
CV_R	19,5%	12,8%	8,4%	9,7%	7,0%	7,8%	7,0%

Internal round robin test – BMP III

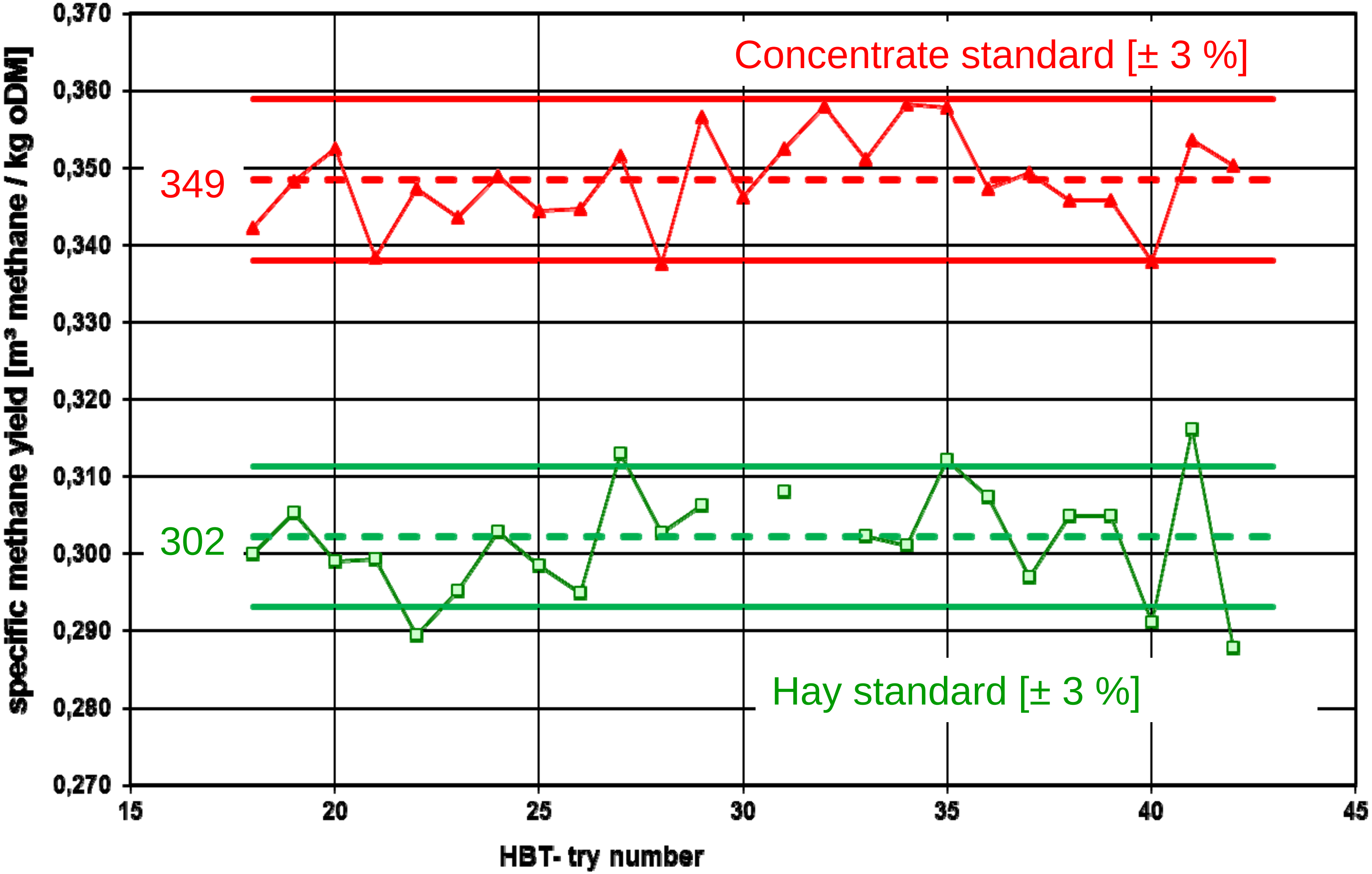
Maize silage, dried and grinded

- Deviations
- Cause analysis
- Inoculum?
- Test equipment?
- Calculation mistake?





Standard substrates in Batch tests
[strict requirements – only ± 3% deviation]



Planned Round robin test in the BMP III - program

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Schedule

- Use of all inocula of 4 partners (+ starving out inoculum)
- Substrates:
  - Concentrate
  - Microcristalline cellulose
  - Dried maize silage
  - Fat-rich fodder
- Variants with trace elements
- ➢ 6 replications of each variant

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Balance study

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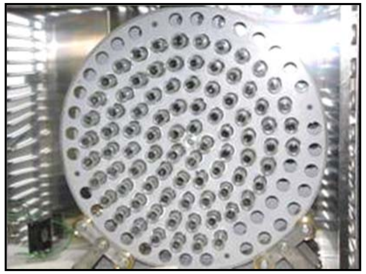
1 bomb calorimeter

substrate

maximal energycontent

2 HBT batch-test

substrate + inoculum



methane yield

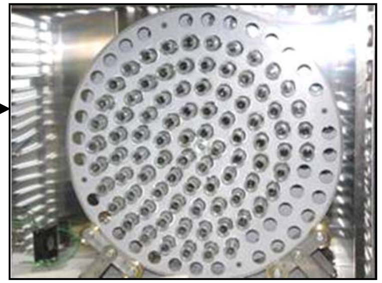
3a continuously digestion

substrate + manure

methane yield like in practise

3b residual methane potential

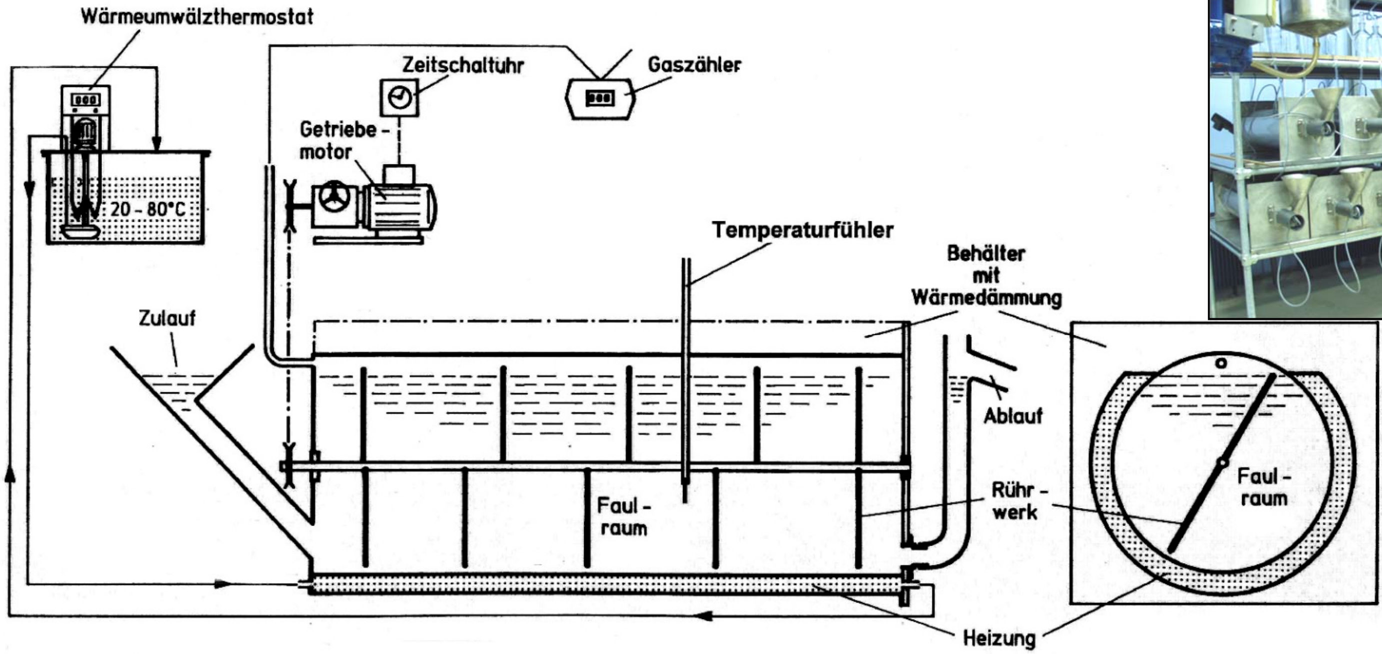
digestate from cont. digestion



residual methane potential

Mukengele,Ciza, Oechsner 2006

Continuously laboratory biogas test



15 digester, each with 17 l

Substrate: maize silage, crushed wheat grain, mixture of both (1:1)

Digestion temperature: mesophilic, 37°C ± 1°C

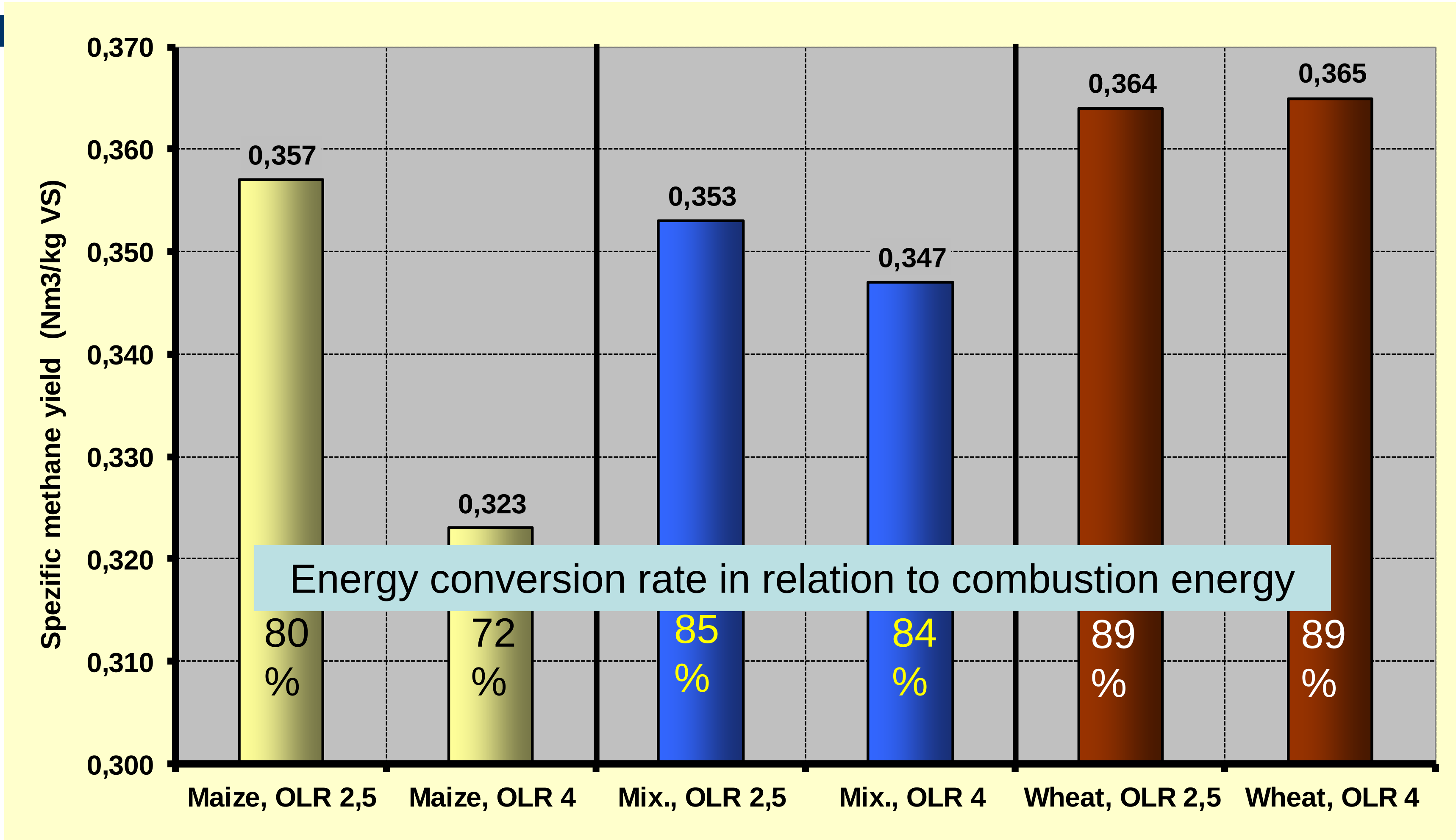
OLR: 2.5 respetively 4.0 kg VS/m³*d

HRT: 35 days

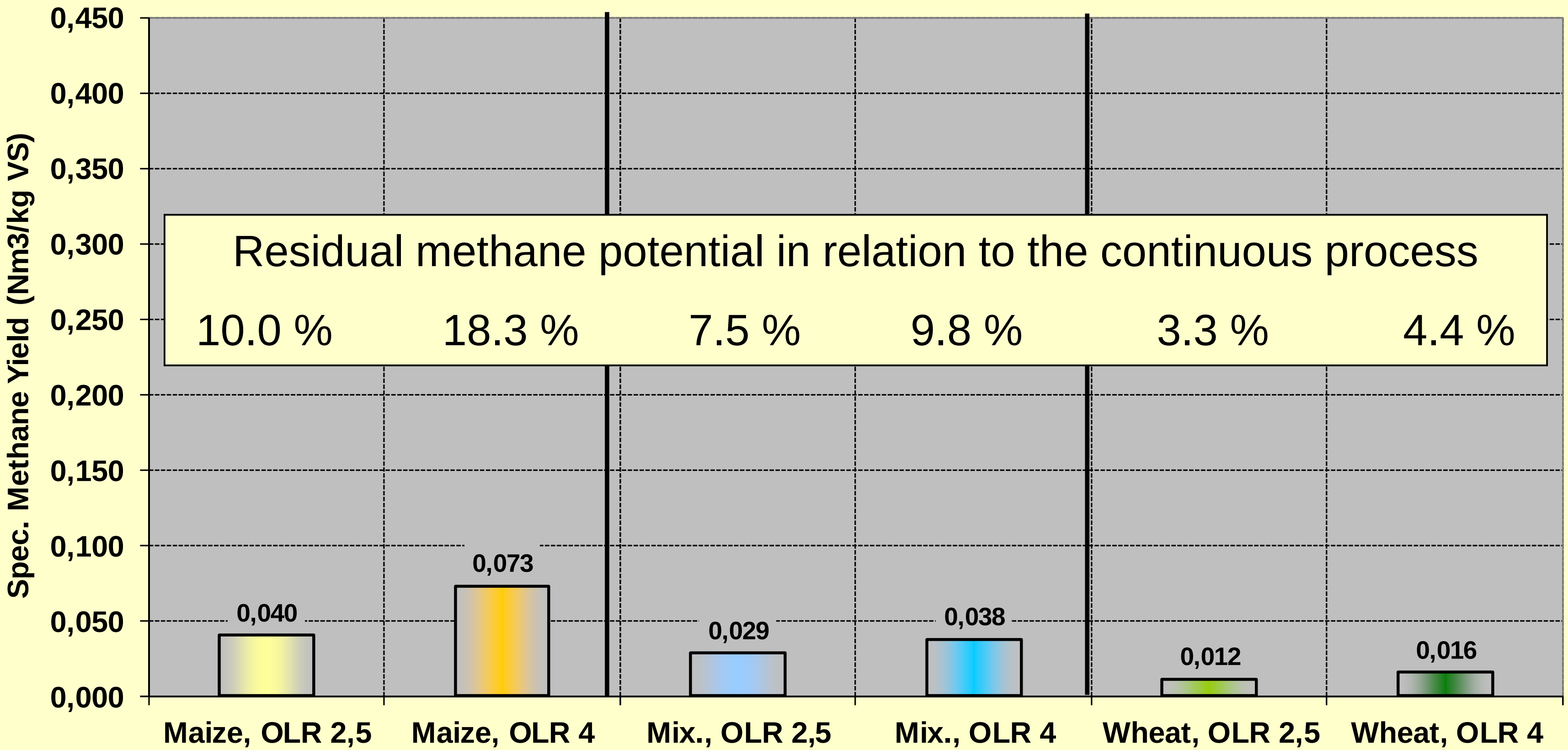
Duration: 123 days

2 replications

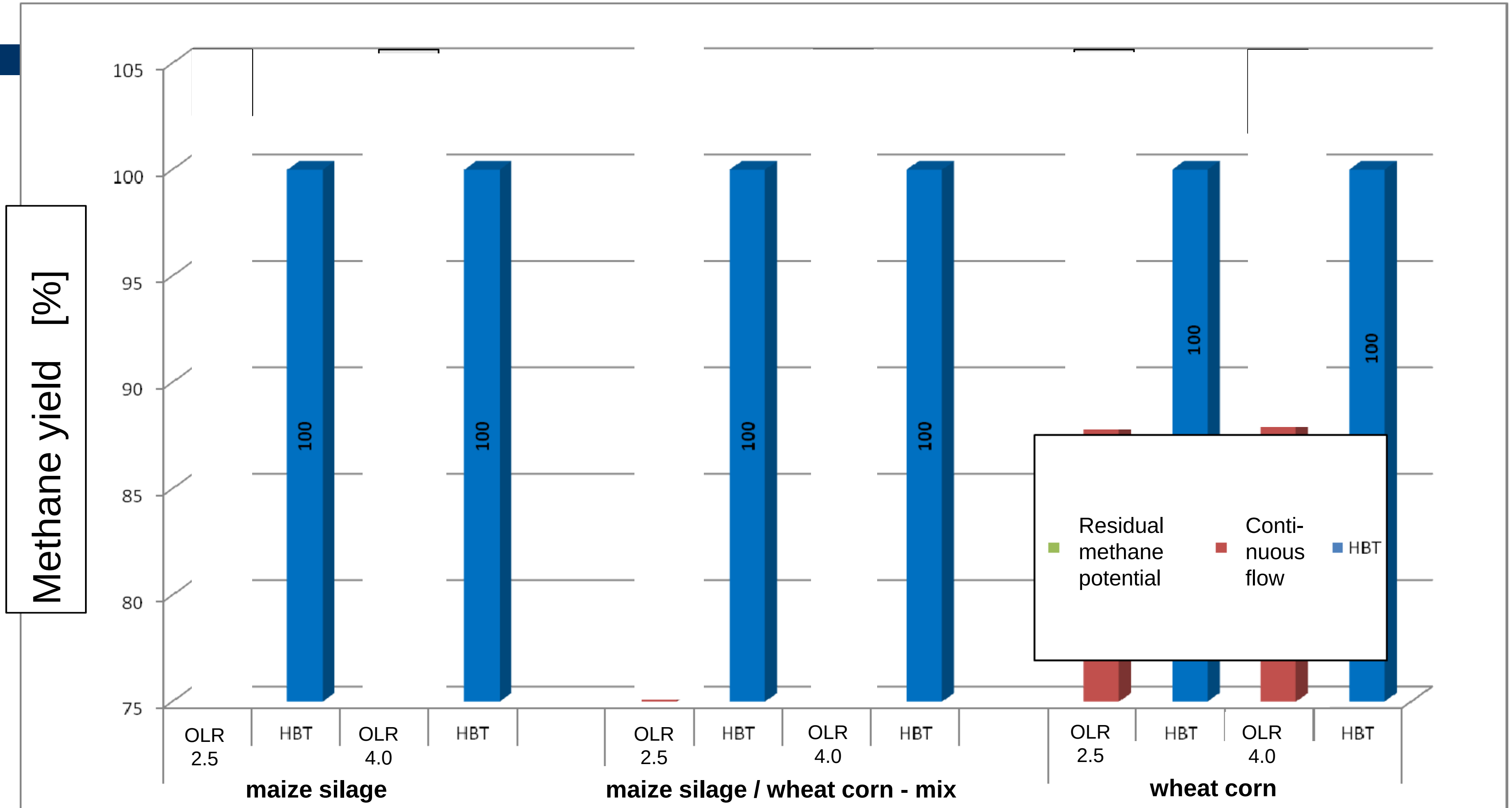
Methane yield at continuous digestion in laboratory



Methane yield at continuous digestion in laboratory - digestate



Comparison of results from bach- and continuously running laboratory digester



Total energy conversion rate in relation to combustion energy						
88,4 %	88,2 %		92,3 %	93,0%	92.0%	93,0%

Contrast of procedures Batch - Practise

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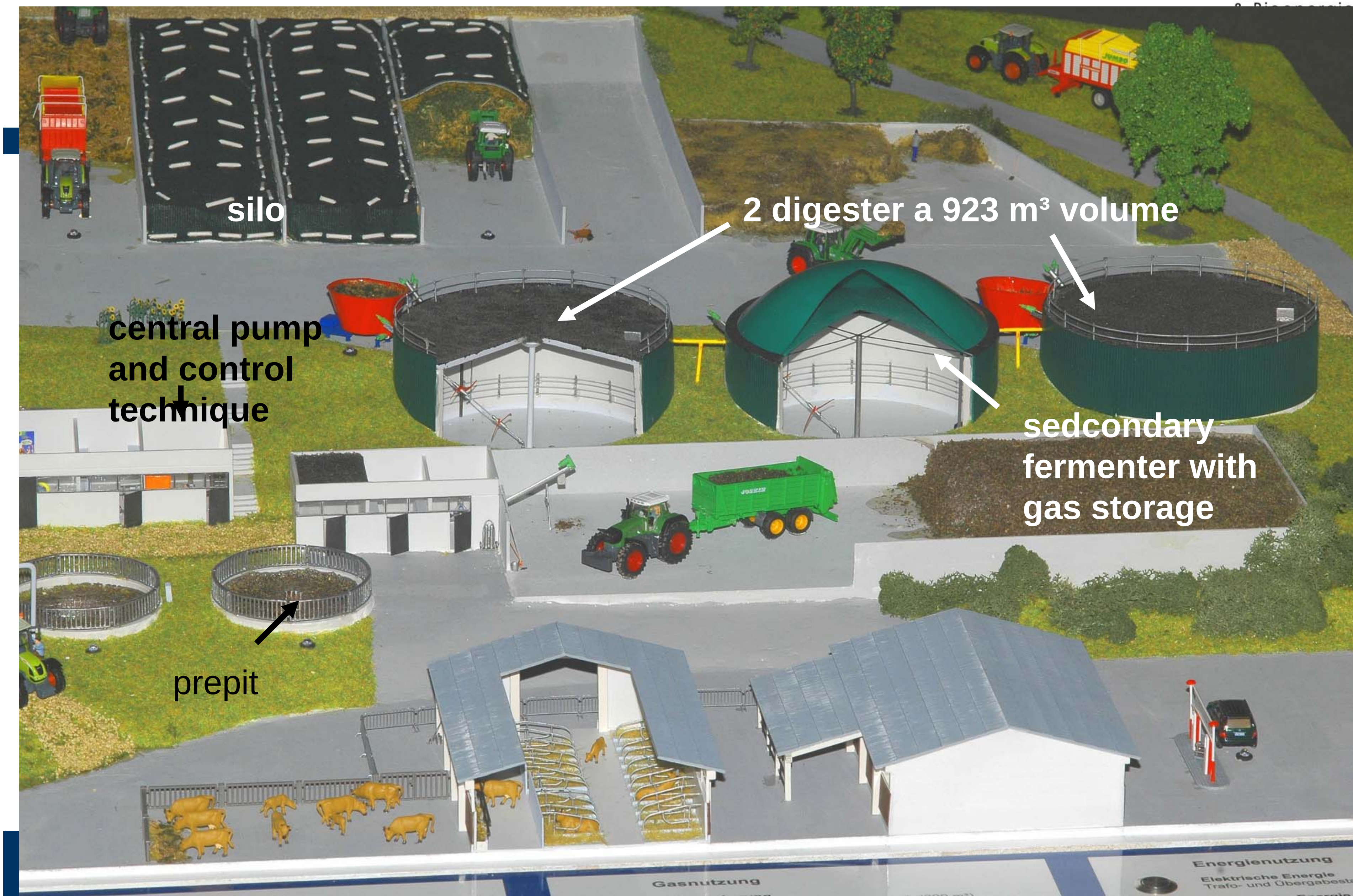
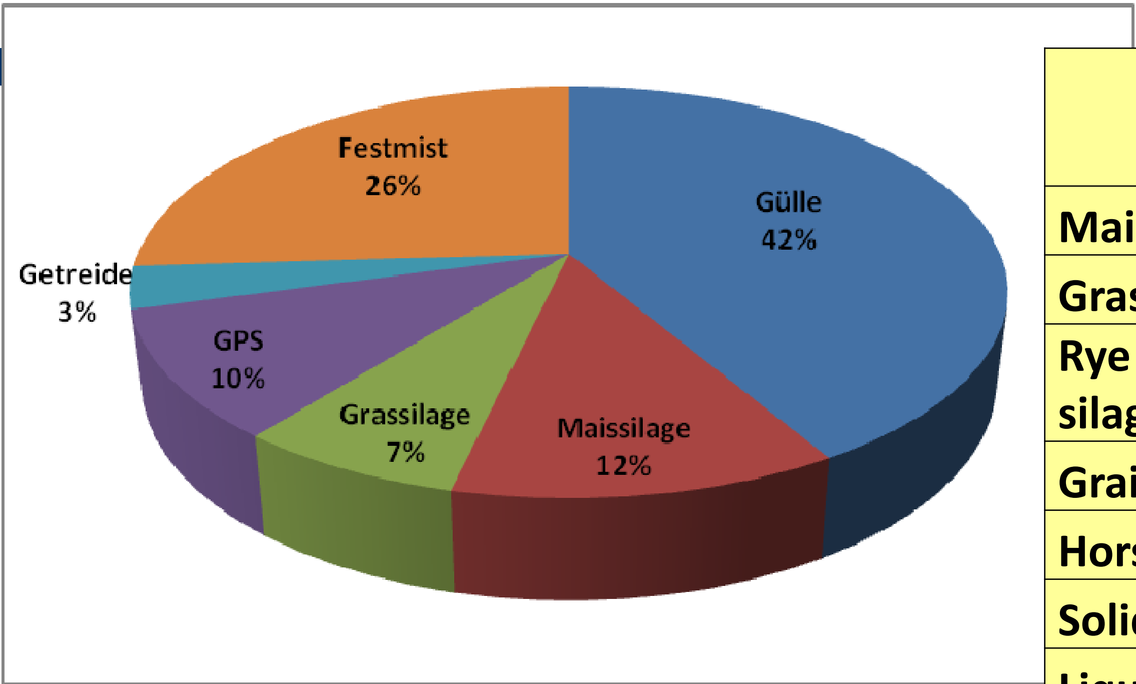
Paramater	Batchversuch	Praxis-Biogasanlage
Digestervolume	100 ml – 15 l	> 2000 m³
Mode of operation	No exchange of material	Continuous feeding Recycling of digestate
Biological process	Steps of degradation are running in series	Steps of degradation are running parallel
Loadingrate	Up to 50 g oDM / l DV*d At the start of test	2 - 5 g oDM / l DV*d
Retention time	35 days	mostly > 100 days z.T. digester cascades
Substrate	Regular monosubstrates, representative, homogeneous	Mostly substrate mixtures different composition Changes in silo possible Volume of manure often not measured
Measuring equipment	Precise weighing of inoculum and substrate possible Precise measuring of methane yield and -quality	Weighing units not exact Gascounter not calibrated Gasquality often not detected

Full scale research biogas plant „Unterer Lindenhof“



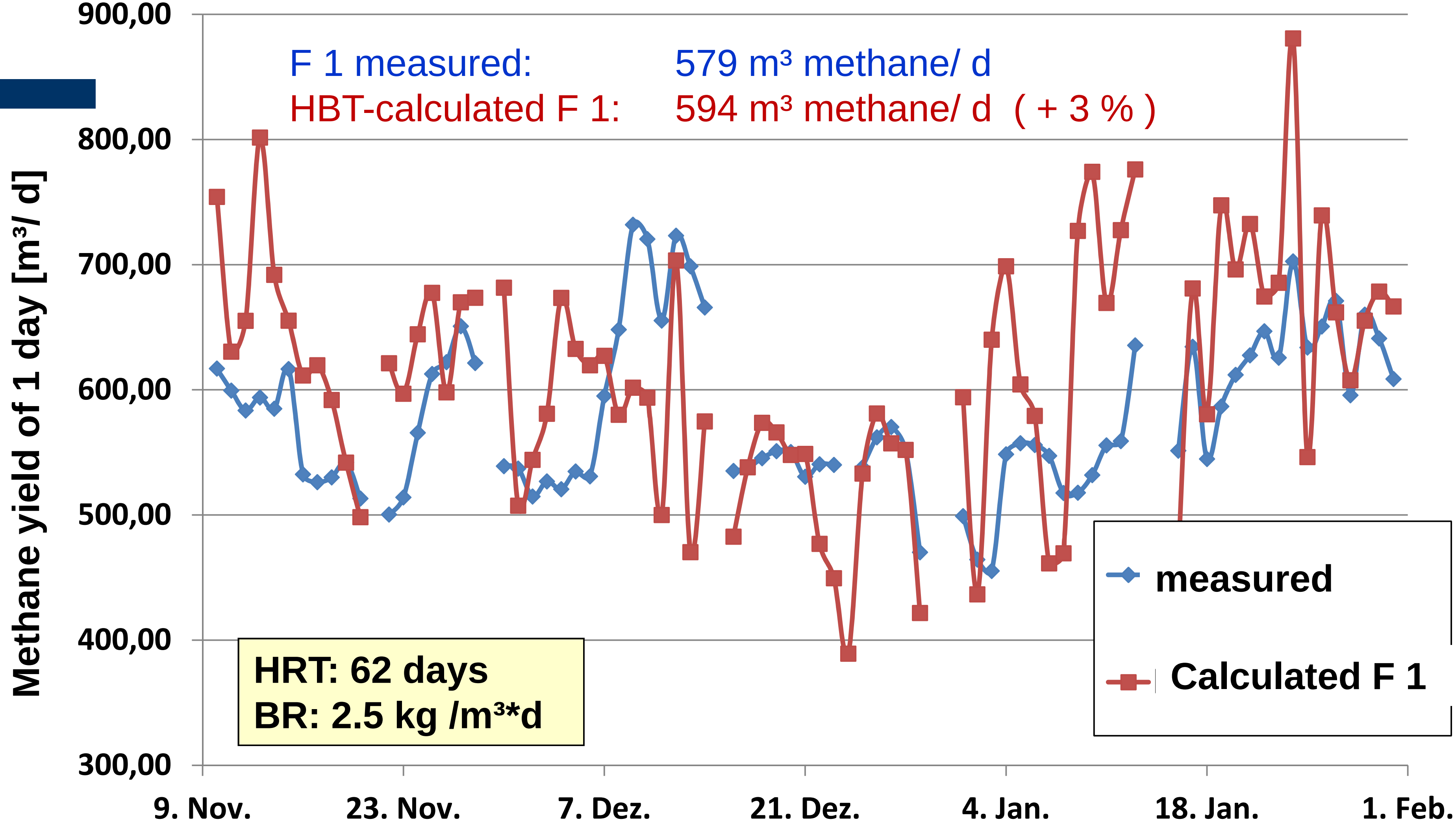
Conditions of biogas plant, digester 1



	Methane yield m³/kg oDM
Maize silage	**0.376**
Grass silage	**0.351**
Rye whole crop silage	**0.336**
Grains crushed	**0.395**
Horse manure	**0.224**
Solid manure	**0.265**
Liquid manure	**0.180**

Hydraulic retention time:	62 Tage
Loading rate:	2.5 kg /m³*d
feeding:	12 x per d
Sampling of DM, oDMt:	each week
Methane yield test:	each month

Methane yield in full scale plant



Mönch-Tegeder, 2013

Specific Methane yield in full scale plant

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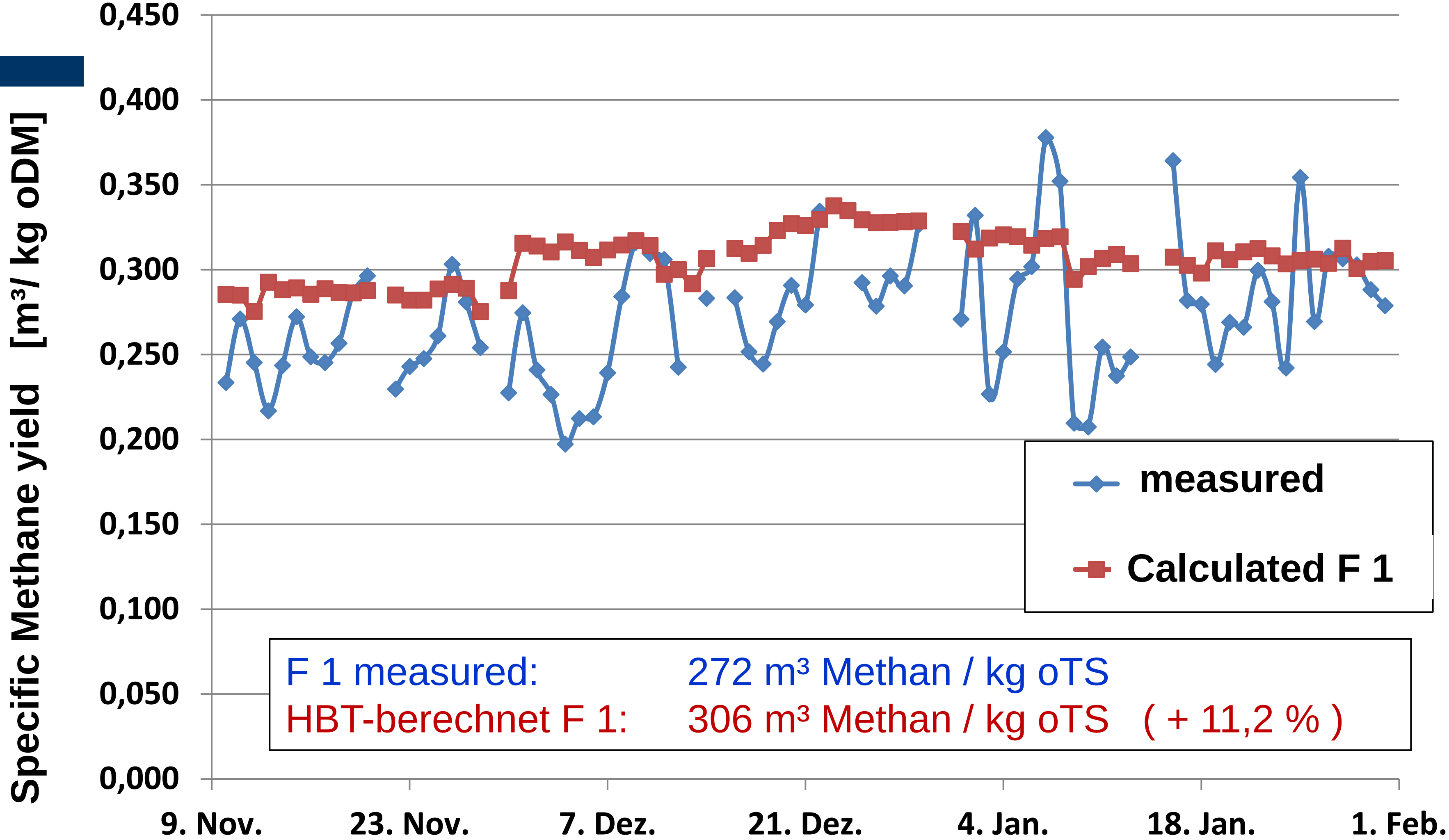

Mönch-Tegeder, 2013

Conclusions

- BMP III will demonstrate the state of the art with 60 modern biogas plants
- A great number of measuring parameters are used regularly
- It is essential to ensure the quality of this parameters
- With the cross-sectional topics we will optimise the measuring methods for better prediction of balance parameters
- Examinations show that laboratory results are relatively good transferable to full scale
- But the methods must be improved continuously
- Exact weighing, measuring of gas volume and gas quality is difficult in full scale plants
- Substrate composition is changing continuously

Thank you very much for your attention!

Thanks to FNR and BMEL for funding BMP III

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