Efficiency of Biogas Processes

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ZNES
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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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Innovative Fermentation Technologies

Adapt the reactors to the microbial processes

Make anaerobic digestion robust against sudden substrate changes (shock loads)

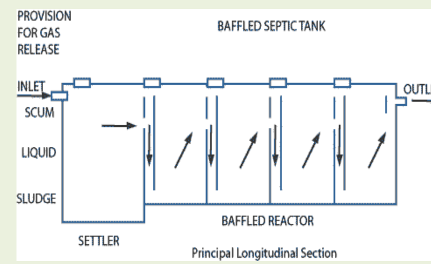
Increase concentrations of value added products in the reactor like the ruminants do

Keep the actors (catalysts or micro organisms) always in the fermenter

Transfer the whole feedstock into value added products

Make it simple, robust and standardized: fermentation in containers

(M)ABR Technology



→ Start-Up Company Conviotec GmbH

In contrary to all other bioenergy options (except combustion)

WHY BIOGAS TECHNOLOGY WILL HAVE A BRIGHT FUTURE

Reasons for Biogas Production

Substrate	Main Goal	Attractive Goal	Additional Goal	Renewable Energy Regime
Wastewater	Disposal	Nutrients Recycling	Energy Production	
Waste	Disposal	Nutrients Recycling	Energy Production	
Manure	Disposal	Nutrients Recycling	Energy Production	
Energy Crops	Energy Production			Power to Chemicals
Integrated Farming Biorefinery	Technical Destruent	Nutrient Recycling	Energy Production	Power to Chemicals

Highly Flexible Portfolio

Allows allocation of costs depending on particular incomes and market opportunities:

- Technical destruents as environmental service
- Back to the roots – organic degassed fertilizer as a value added product
- Two new opportunities in renewable energy regimes

=> Need for efficient processes

EFFICIENCY OF BIOGAS PLANTS

Efficiency Activities

- RoI dependend on process efficiency
- In Germany: Remaining term of feed in tariff security – what happens thereafter?
- Singular control of biogas potential is not relyable for economic risk calculations

Consequences

- Continuous control strategies with adapted analytical tools needed:
  - Biomethane potential test needs 60 days
  - FoTS based on general statistical considerations
  - **Method of 100% based on time series control and HHV determination**

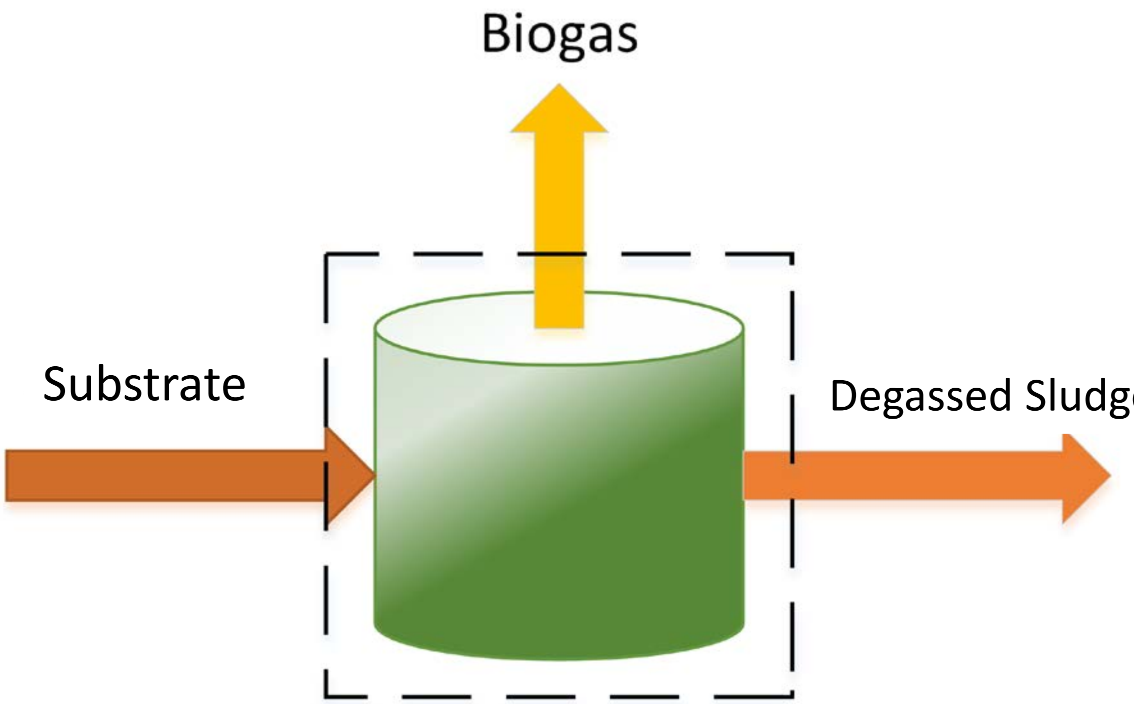
Motivation and Goal:

- Methode of theoretical 100%: analysis of more than 200 biogas plants -> high variance width in efficiency
- Long term control in reasonable frequencies allows more detailed information:
  - Sampling
  - Saisonal variations
  - Substrate quality and –quantity
  - accidents

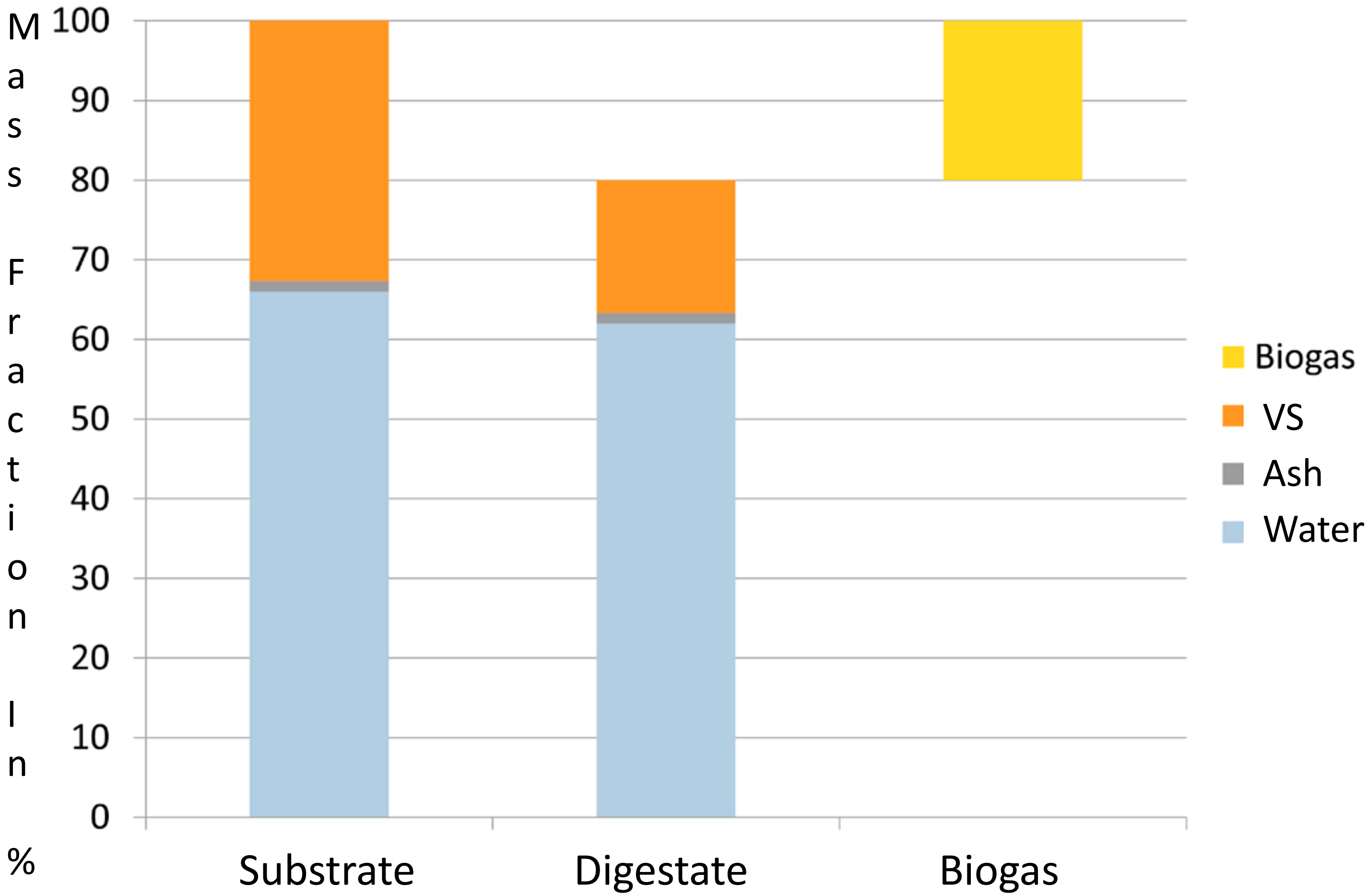
Time Series Analysis

- Statistical method to control quality of products and processes variances (storage of silage)
- Allows to identify time shifts between input and output streams caused by kinetic processes (hydraulic retention times in biogas processes) and influences of changes in the input streams to the process output

Sampling during Time Series Analysis



Overall Mass Balance



Determination of Energy Content: Methode of Theoretical 100%

- Energy content of substrates and of digestate determined by :
  - Higher heating value (HHV) determination (preliminary drying required)
  - Determination of total solids (TR) and ash content:

$$E_i = m_i \cdot TR_i \cdot HHV_i$$

Absolute Efficiency:

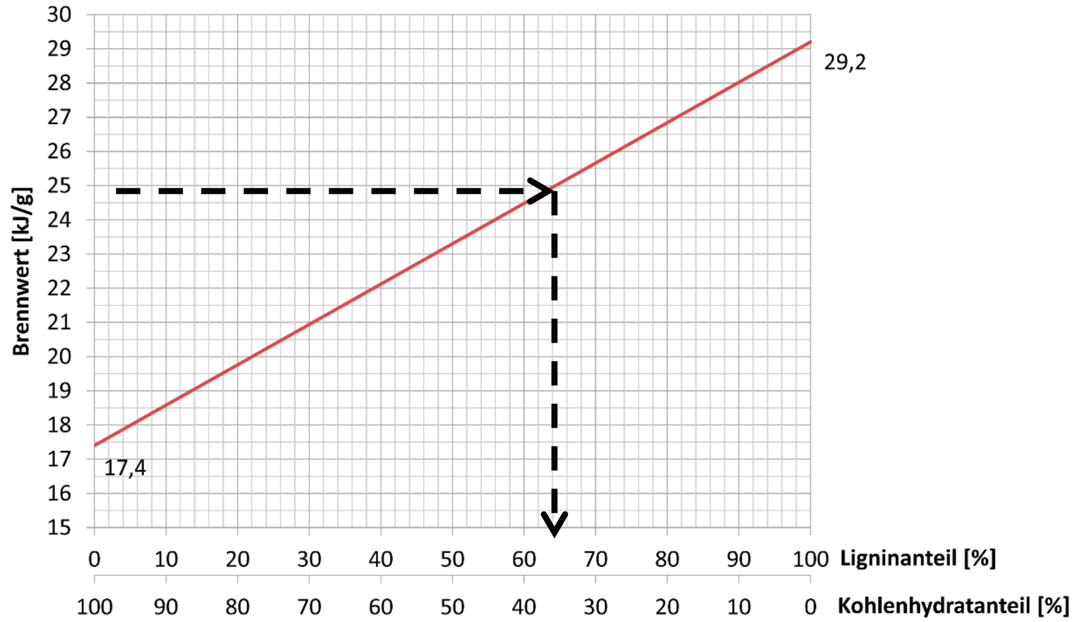
$$\eta_{abs} = \frac{\text{Energy Input} - \text{Energy Output}}{\text{Energy Input}} = \frac{\sum_S \dot{m}_S \cdot TR_S \cdot HHV_S - \sum_{GP} \dot{m}_{GP} \cdot TR_{GP} \cdot HHV_{GP}}{\sum_S \dot{m}_S \cdot TR_S \cdot HHV_S}$$

Methode of Theoretical 100% further assumptions

Energy in the digestat is based on non digested carbohydrates and lignin:

1. Anaerobically digestable: carbohydrates like cellulose and hemicellulose
2. Inert material: lignin

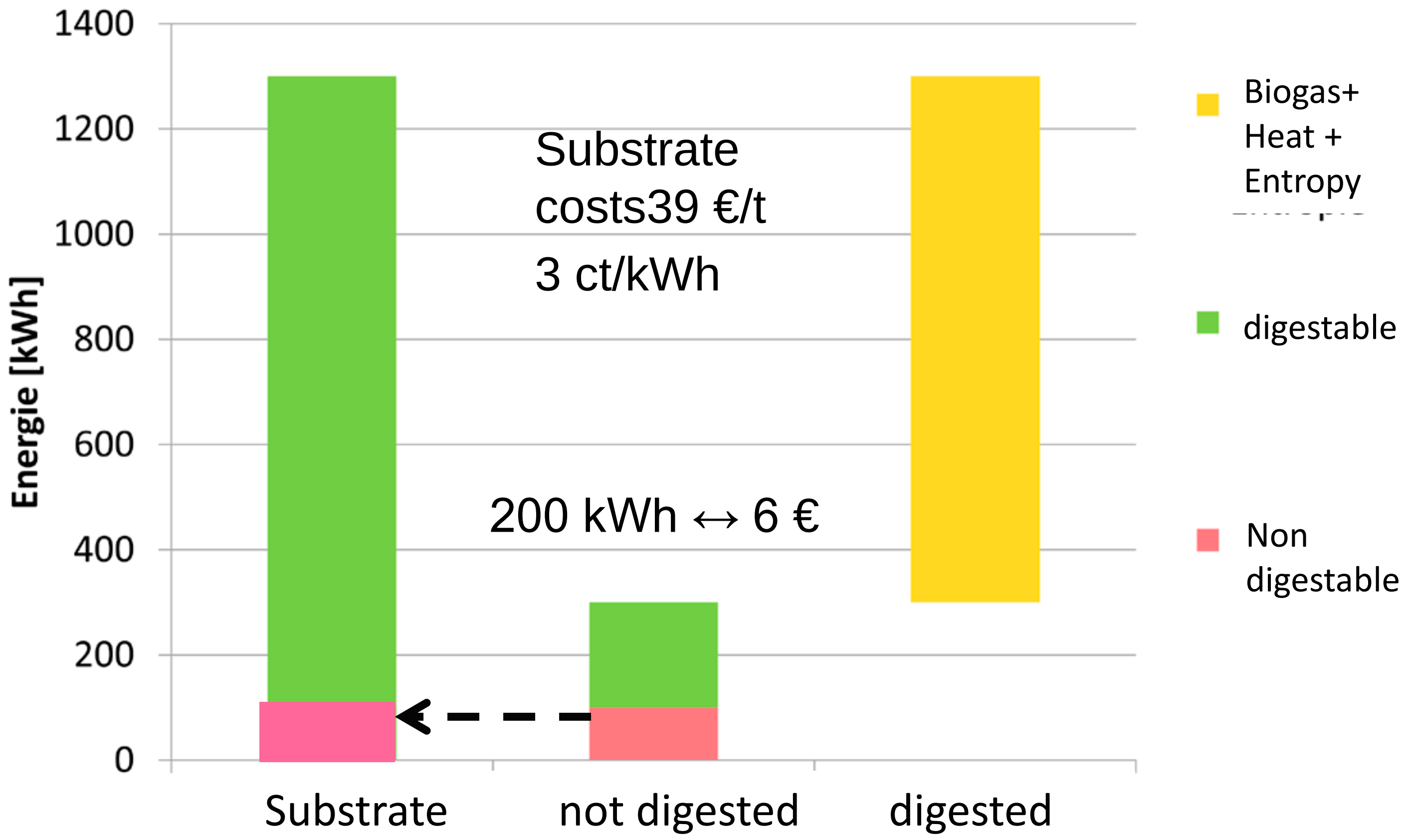
HHV of Binary Mixtures



$$\eta_{\text{digestable}} = \frac{\text{Digestable Energy Input} - \text{digestable energy Output}}{\text{Digestable energy Input}}$$

$$\eta_{\text{digestable}} = \frac{\sum_S \dot{m}_S \cdot TR_S \cdot HHV_S - \sum_{GP} \dot{m}_{GP} \cdot TR_{GP} \cdot HHV_{GP}}{\sum_S \dot{m}_S \cdot TR_S \cdot HHV_S - \sum_{GP} \dot{m}_{GP} \cdot TR_{GP} \cdot oTR_{GP} \cdot w_L \cdot HHV_L}$$

Efficiency Related to Digestable Content



Sampling and Analytical Procedures

- Weekly sampling
  - VDI 4630, feste Stoffe an 6 verschiedenen Stellen
  - Flüssige Stoffe nach kräftiger Durchmischung der Behälter
- Determination of total solids (TR)
  - DIN 38414 S2
- Determination of ash content
  - DIN 38414 S3
- Determination specific HHV
  - DIN 51900 S3, 3-fach Bestimmung

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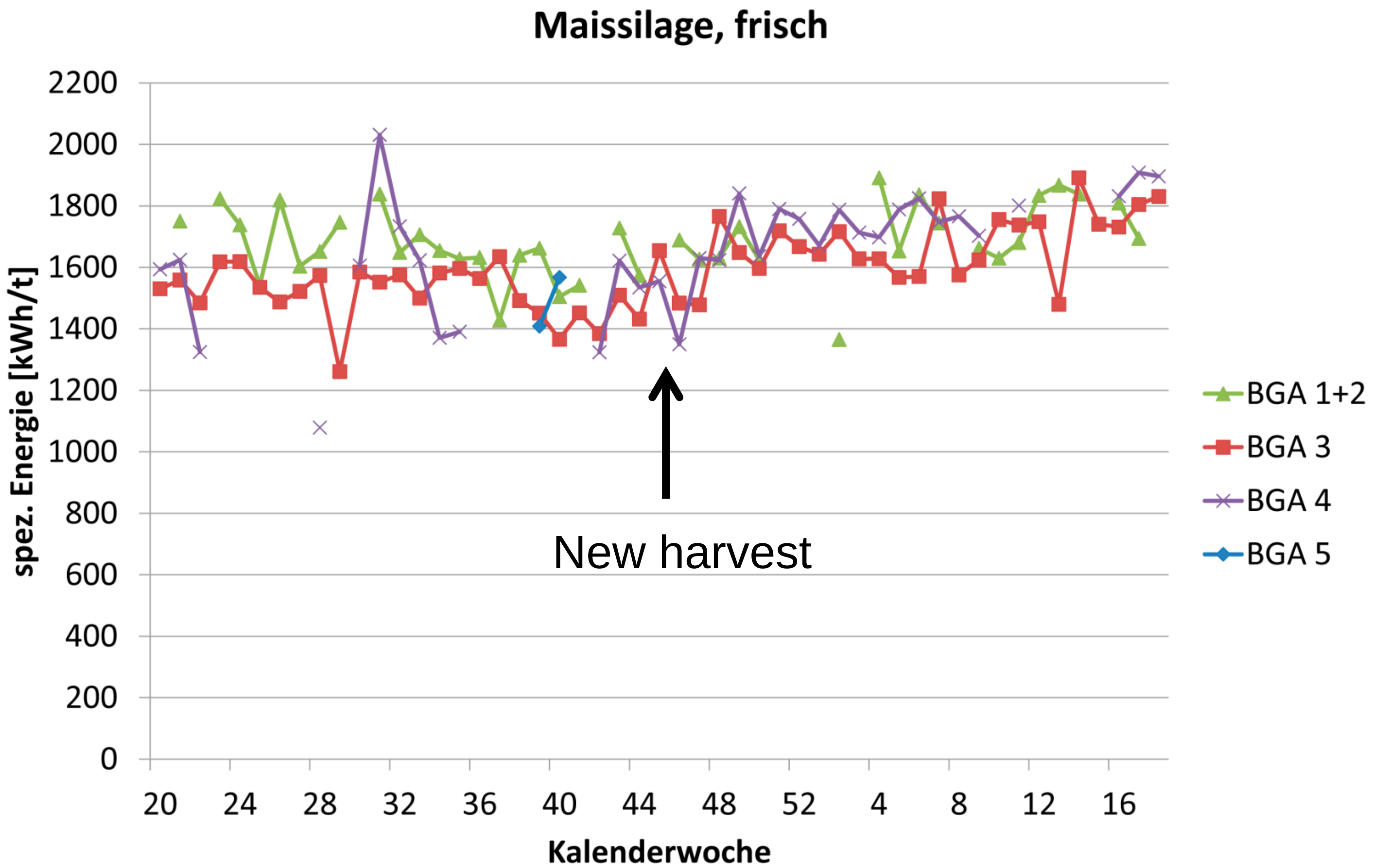
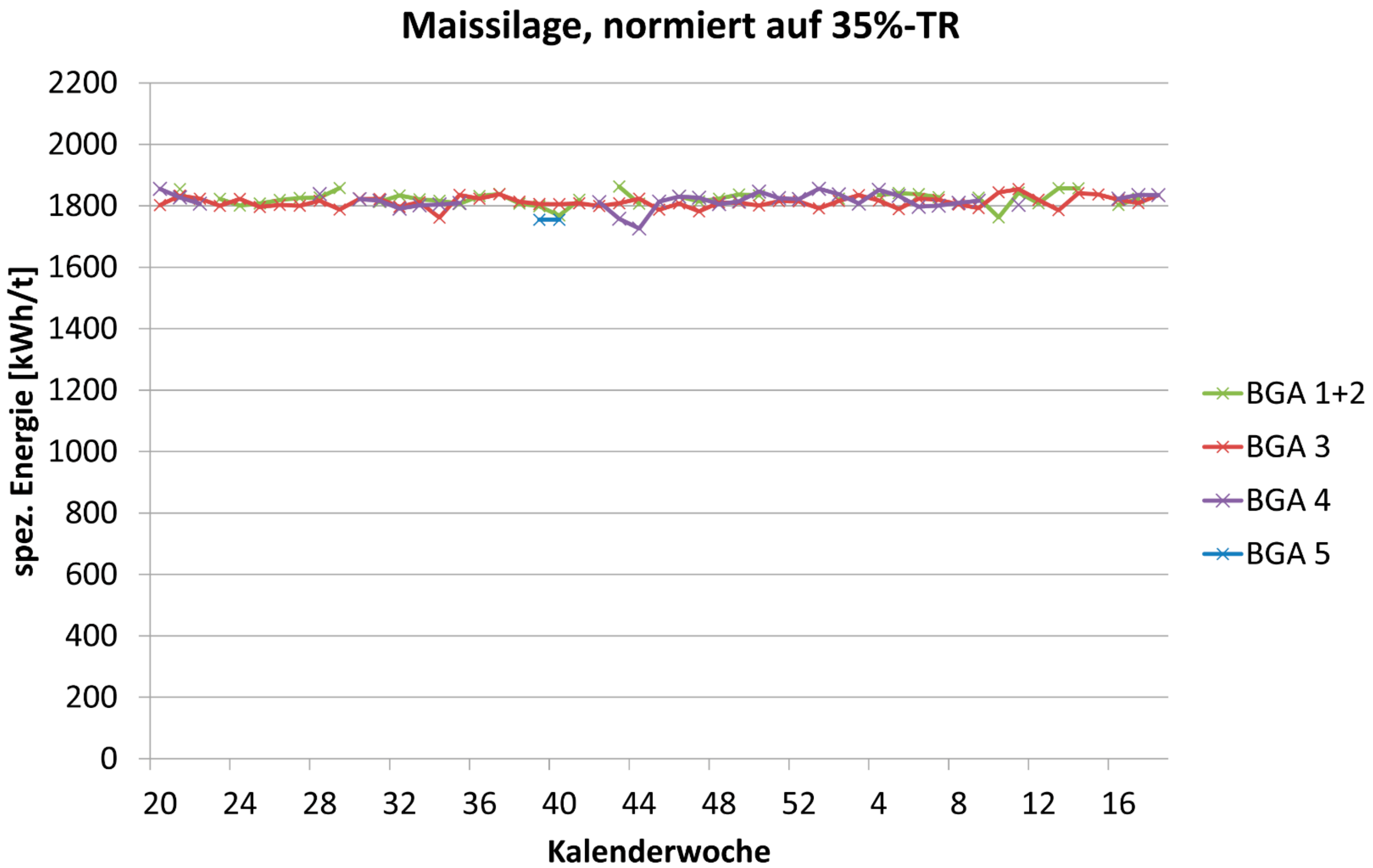
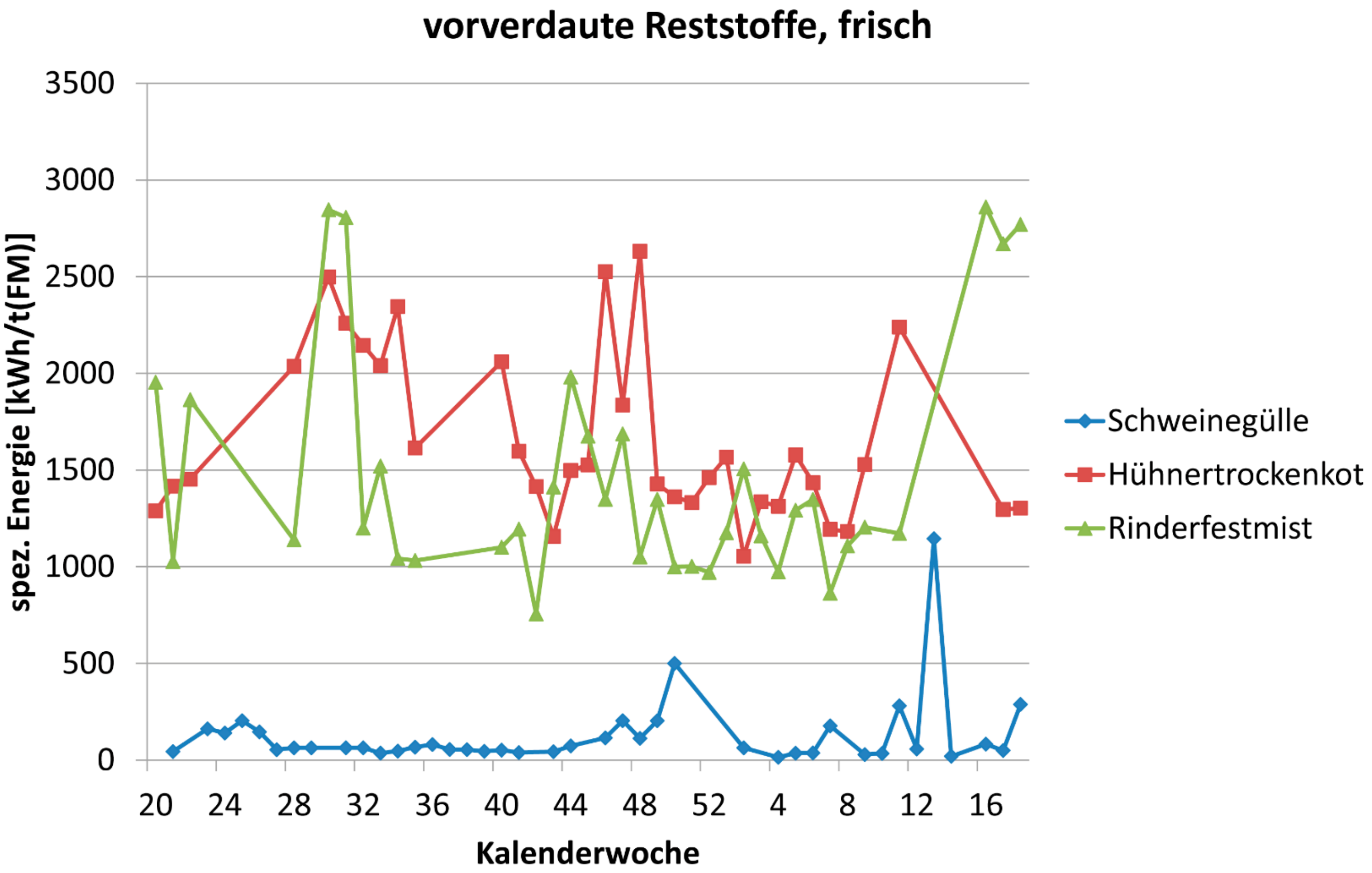
Results: Substrates (Corn Silage)



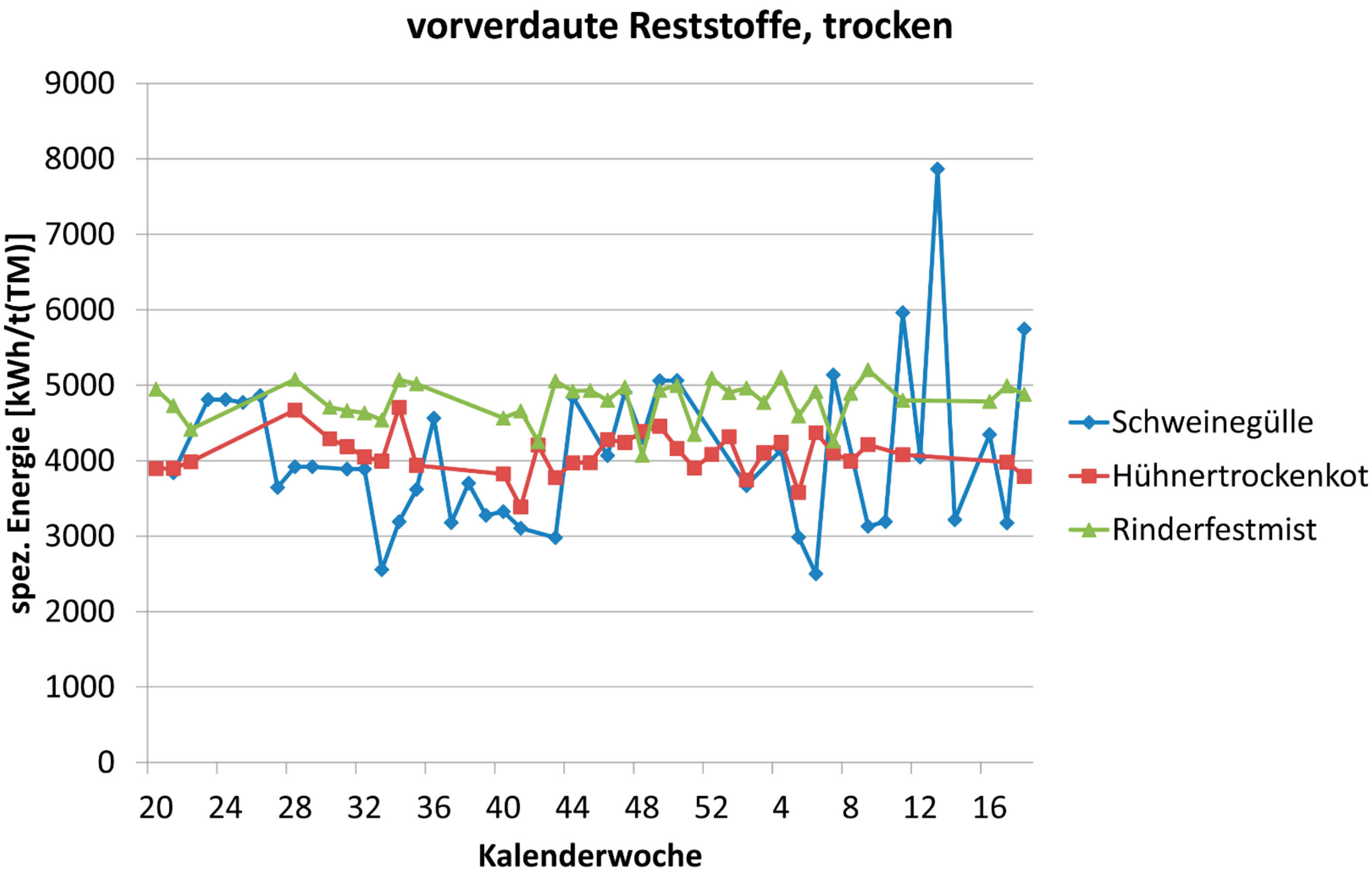
Ergebnisse: Substratvergleich (1)



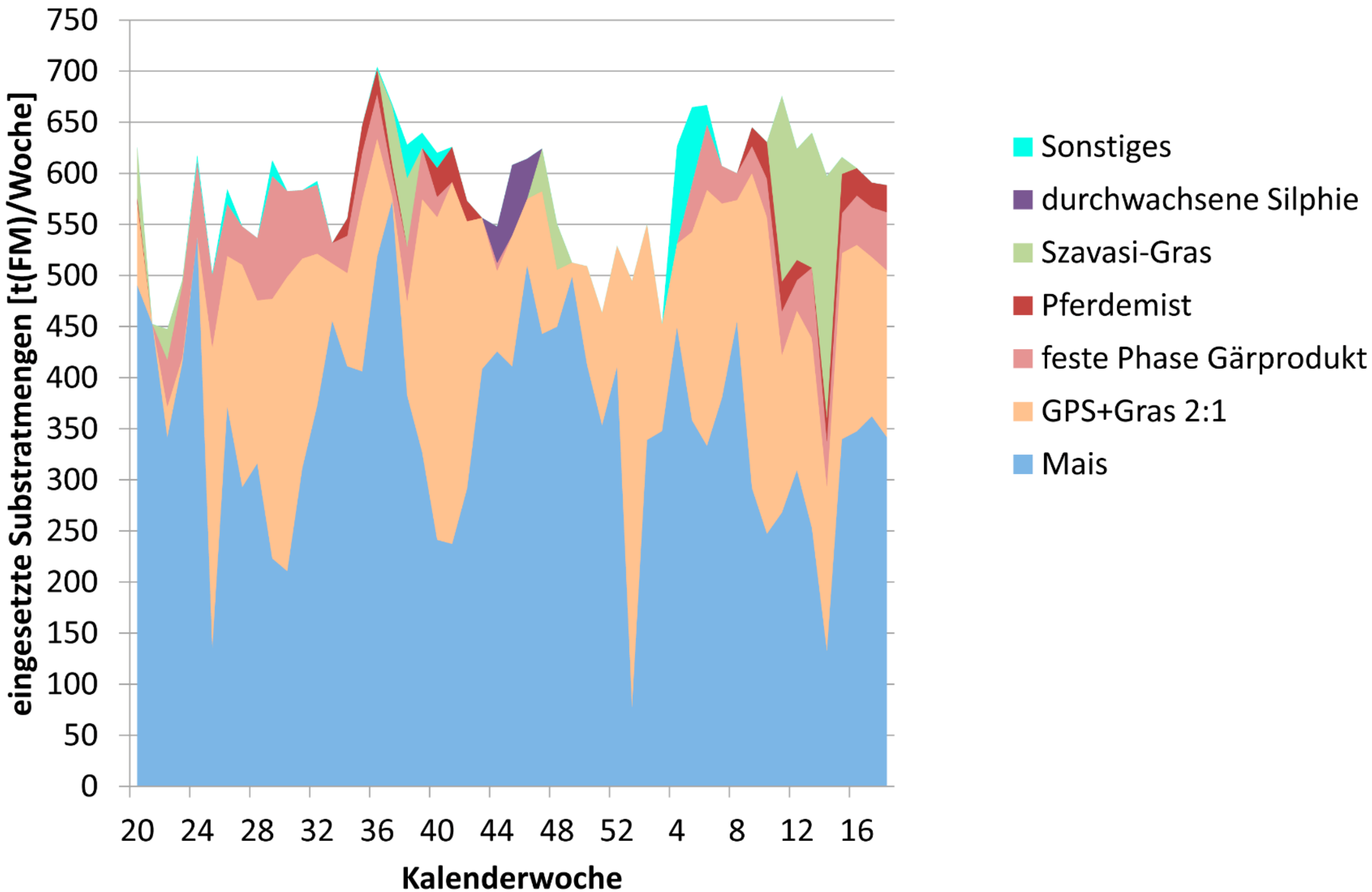
Results: Substrates (Manures)



Results: Substrates (Manures)



Results: Efficiency Development



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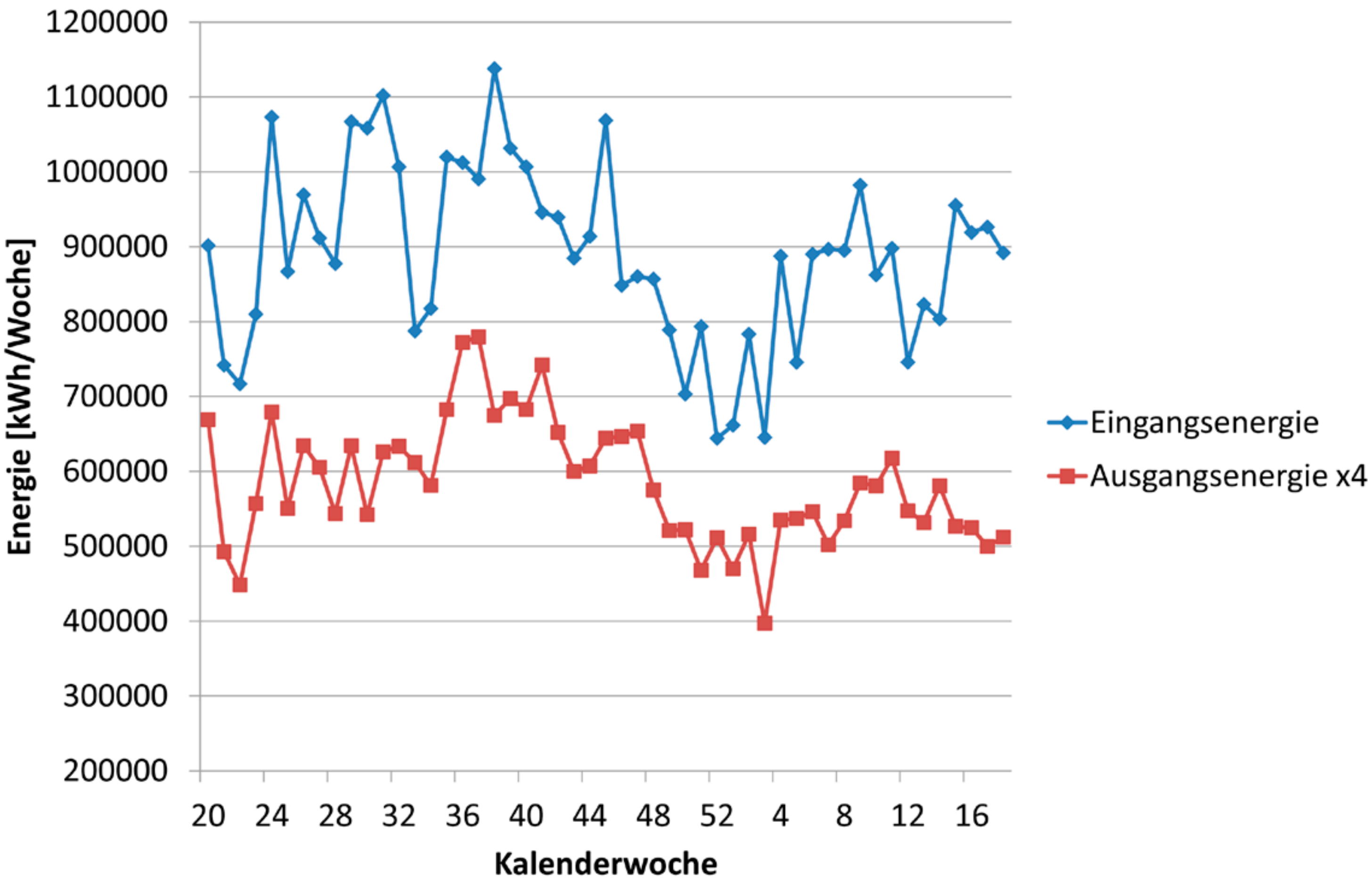

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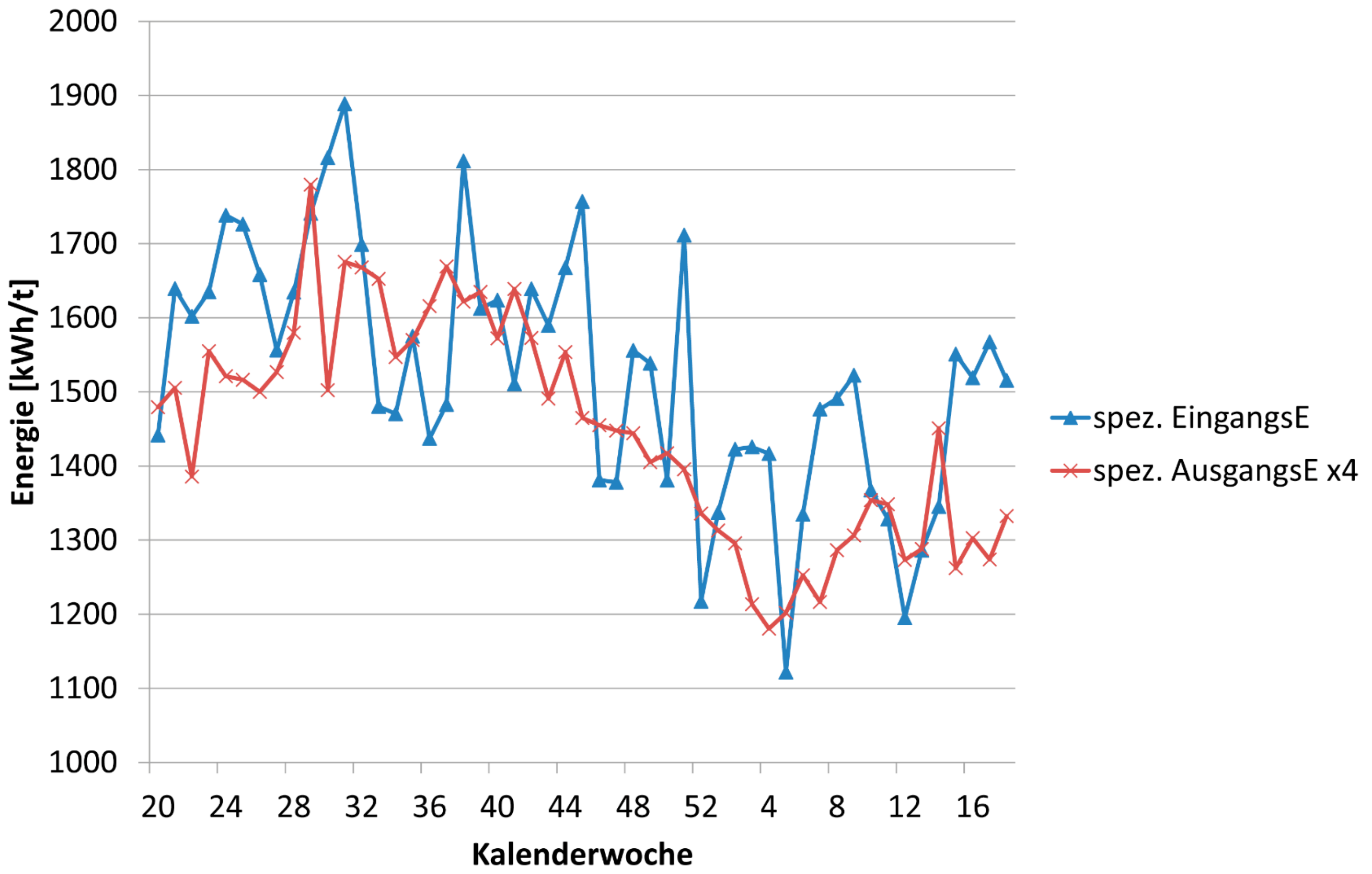

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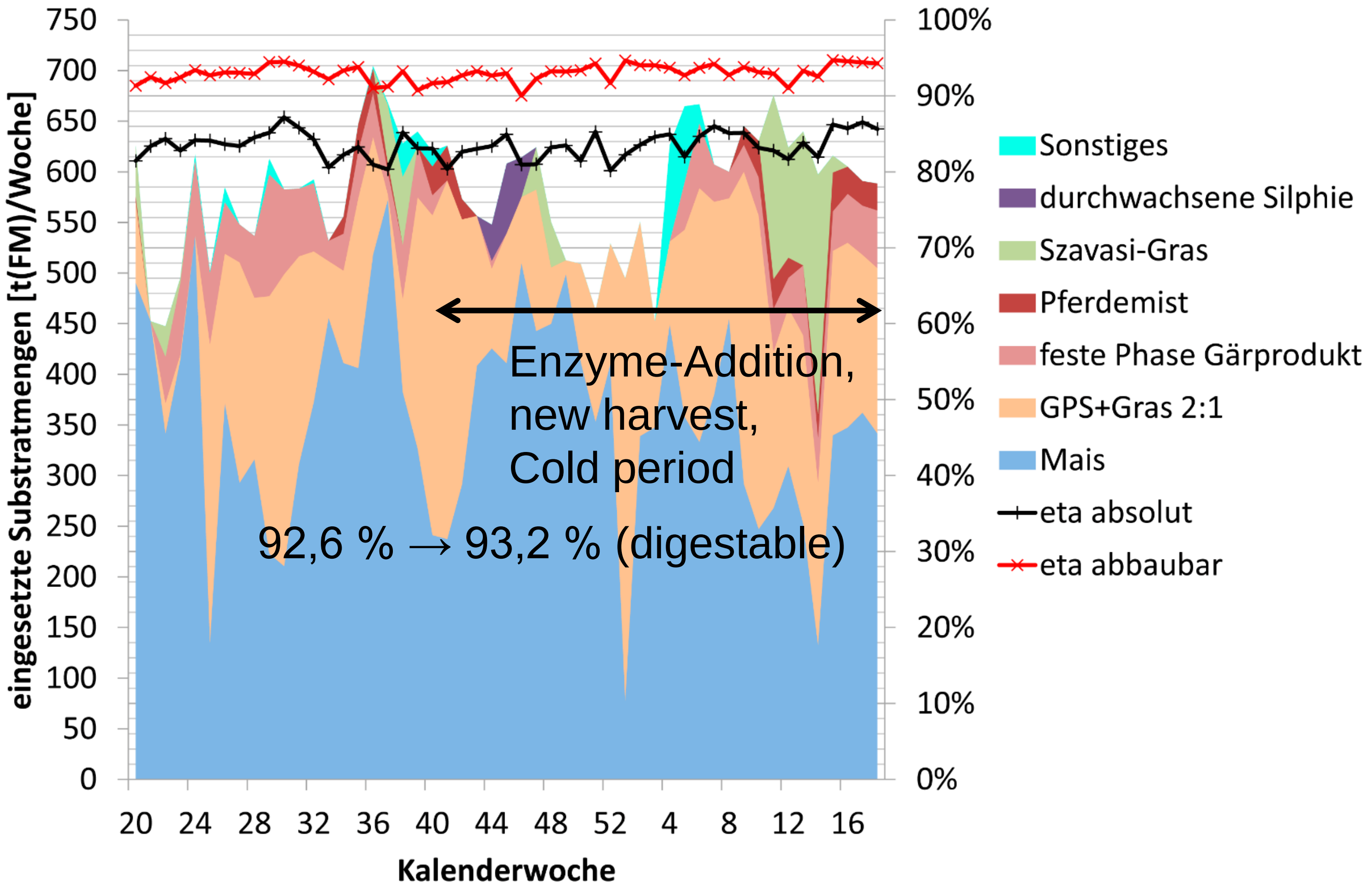

Conclusion

- Efficiency is dependend on substrates quality and quantity
- Substrate chances have a negative effect on efficiency
- Efficiency varies higly

Time series analysis is important for efficiency control

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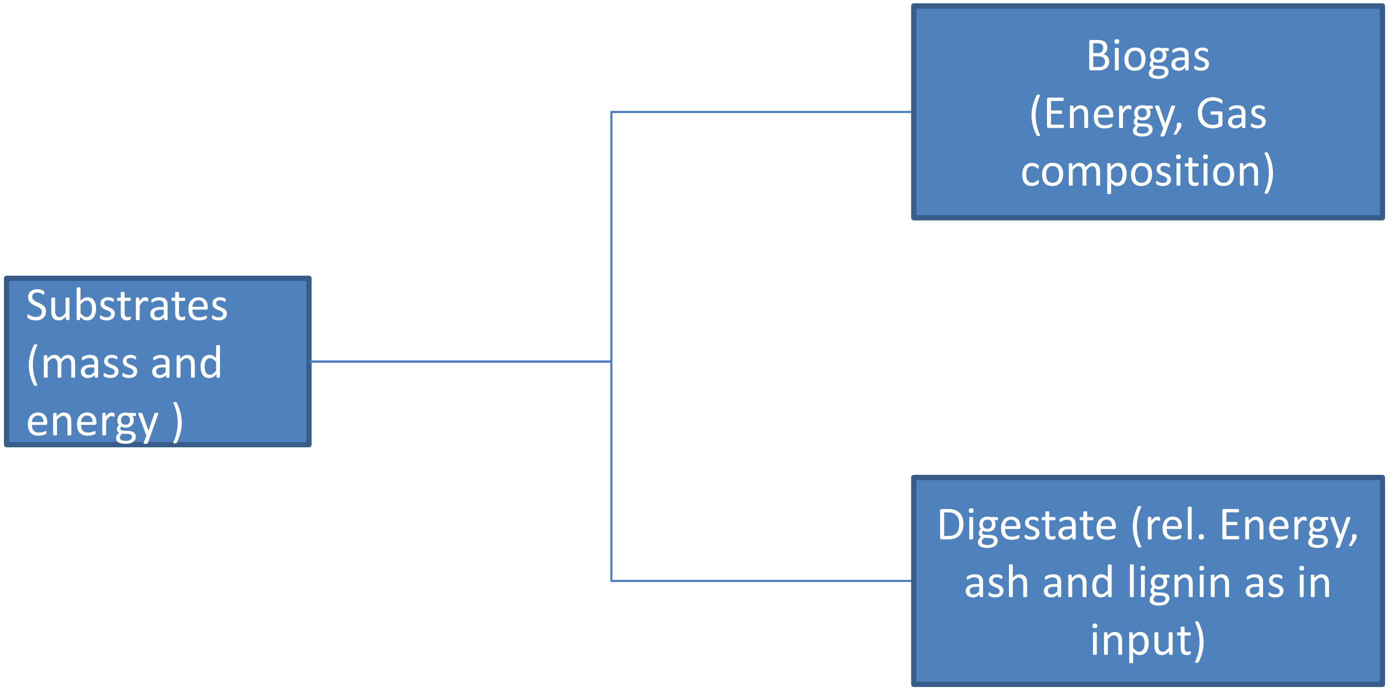
Derived Simulation Approaches

- Mass and energy balances of cmercially running biogas plants are usually incomplete
- Results of the time series analysis and the methodology of the 100% allows a reasonablbe and representative modelling of mass and energy balances of biogas plant processes
- Relyable mass and energy balances are prerequisite of efficiently running biogas plants

Derived Simulation Approaches



Derived Simulation Approaches

Nutzenergie								Angaben aus Betriebstagebuch			
BGA	550	kWel									
Wirkungsgrad BHKW	40,45%							Messwerte			
Vollaststunden	8.322	h/a									
								Ergebnisse			
Feuerungswärmeleistung Gas	11.315.451	kWh/a									
							HHV Lignin	29,2	MJ/kg	8,11111111	kWh/kg
Feed							HHVCellulose	17,4	MJ/kg	4,83333333	kWh/kg
Masse Substrat	8.045.702	kg(FM)/a	6.678.928	bei 100%							
TR Feed	33%										
oTR Feed	97%										
Masse Substrat	2.616.462	kg(TR)/a									
HHV Substrat	18,76	MJ/kg(TR)		5,20972222	kWh/kg(TR)						
Feuerungswärmeleistung Feed	13.631.042	kWh/a									
Masse Lignin im Feed	171.005	kg(Lignin)/a									
GPL											
Masse GPL	444.475	kg(TR)/a									
HHV GPL	19	MJ/kg(TR)		5,25388889	kWh/kg(TR)						
	6,359870341	kWh/kg(oTR)									
oTR GPL	83%										
FWL GPL	2.335.222	kWh/a									
Cellulose	0,53	%									
Lignin	0,47	%									
Masse Lignin im GPL	171.005	kg(Lignin)/a									
Feuerungswärmeleistung Lignin	1.387.037	kWh/a									
Ergebnisse											
Restgaspotenzial	948.185	kWh/a		948.185	kWh/a		100				

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Constraints of the Method

- Collection of volatile substances (organic acids etc.) which can be solved by chromatography and stoichiometric calculations
- Lignin as a prerequisite (reference)
- Sufficient longterm retention time needed –digestate as binary mixture of carbohydrates and lignin
- Difficulty of representative sampling
- Modelling of mass and energy balances with incomplete data sets

Derived Simulation Approaches - Conclusions

- Time series analysis and methodology of 100% allows relyable estimations of mass and energy balances of commercial biogas plants with a mimimum of effort.
- Mass and energy balances shows how much digestable potential energy ends in gas and how much ends in the digestate, i.e. is a potential greenhouse gas
- Nonetheless the efficiency of the biogas plant is not only a need for optimization of the profitablitiy of a biogas plant but also for the greenhouse gas impact

Future Options

- Time dependend shift of energy output under consideration of the retenion time distribution
- Research on competition on utilization via BMP
- Analysis of resulting shift profiles of hydraulic retention times