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Efficiency of Biogas Plants by Time Series Analysis

Presentation at 3rd. Conference on Monitoring and Process Control of Anaerobic Digestion Plants

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Objectives - Time Series analysis of Biogas Plants

- Independent and reliable evaluation of efficiency
- Direct comparsion of up to 70 biogas plants (German, from LSBL 2 and BMP-3, and Danish) with the same method → large database to find relationships
- Practicioner friendly tool with fast response time for determination of the efficiency of the resp. Biogas Plant with consideration of:
  - Plant Configuration
  - Input Materials
  - Profitability of the Plant

Efficiency of Biogas Plants – Methods for determining the efficiency

- **Efficiency is defined as ratio of input energy to output energy**
- Conventionally the efficiency is calculated by batch fermentation test, based on VDI 4630
  - Only representing the moment – reliability?
- Weissbach et. al. using fermentable organic material (FOM) for calculating the maximum expectable gas production of energy crops and manure
  - Using historical data and empirically calculated correction factors

Efficiency of Biogas Plants – Methods for determining the efficiency

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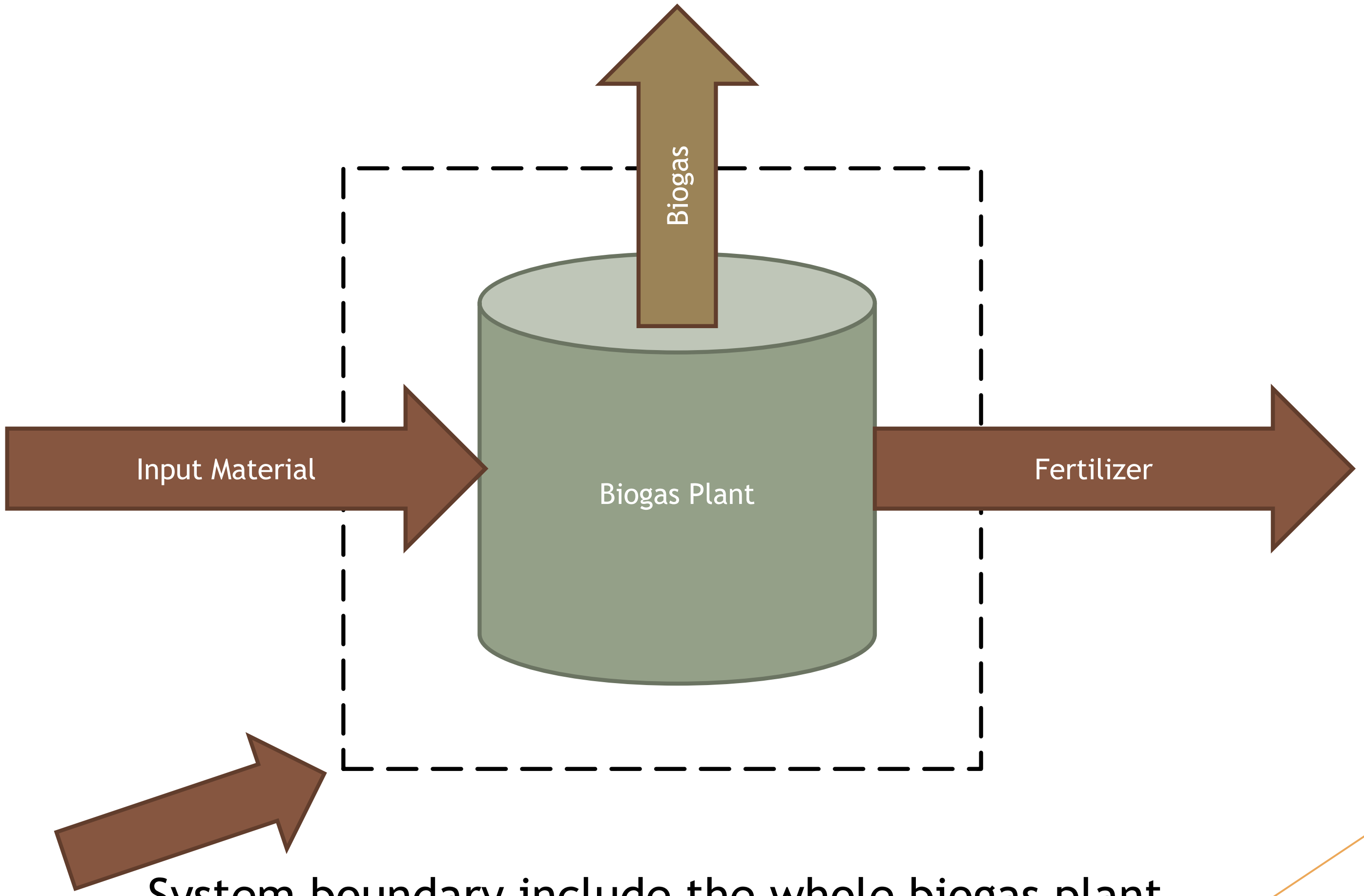
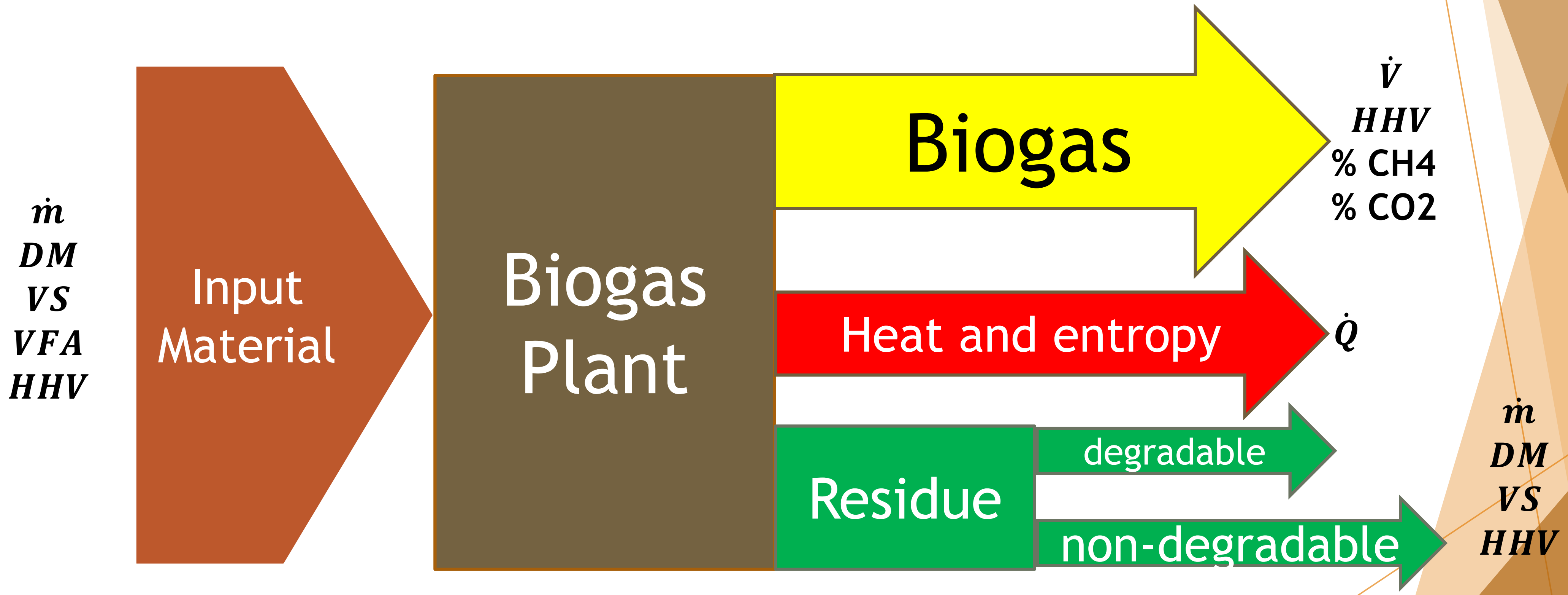
- Empiric calculations by elementary components
  - Using historical data and emipric defined factors
- TOC as Indicator
  - Using measured data sets, system boundaries can include the biogas plant as a whole, single samplings not representative, no determination for the degradable energy is possible
- Calorific value calculations
  - Using measured data sets, system boundaries include the biogas plant as a whole, single samplings only represent instant situations and not representative → time series analysis is a representative alternative

System boundaries at Biogas Plants



System boundary include the whole biogas plant

Mass- and Energy Balance at Biogas Plants



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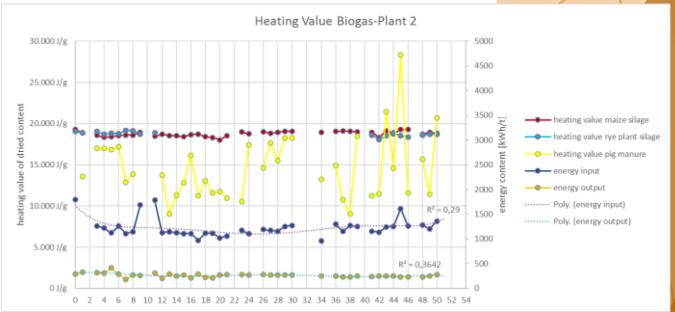
Time series analysis

- Time series analysis allows to show the influence of:
  - process management
  - quality changes of input materials
  - repowering initiatives – pretreatment etc.

- Another benefit of time series analysis:
  - regularities while fermentation can be shown
  - seasonal fluctuations can be shown
  - smoothing of measurement outliers
  - regression models can be created (linear, polynominal)



What we need for Time Series analysis at Biogas Plants

- **For time series analysis it is necessary to know about:**

- input materials (quality and quantity)
- output material (quality and quantity)
- constantly delivered samples of the materials (in min. for one hydraulic retention time of the analysed plant)

Correction factors

- For correct calculation of the efficiency following correction factors are necessary:
  - mass of Sulphur and Nitrogen of the samples
  - volatile organic substances
  - losses of CHP / Gas Upgrading Module
  - losses of permeation by the roof and concrete
  - leachate water of stored biomass; quantity and quality
  - self consumption of bacterias
  - rain water (mass)
  - output material (mass)
  - self consumed electric and heat energy by the plant

1 year time series – Plant Example

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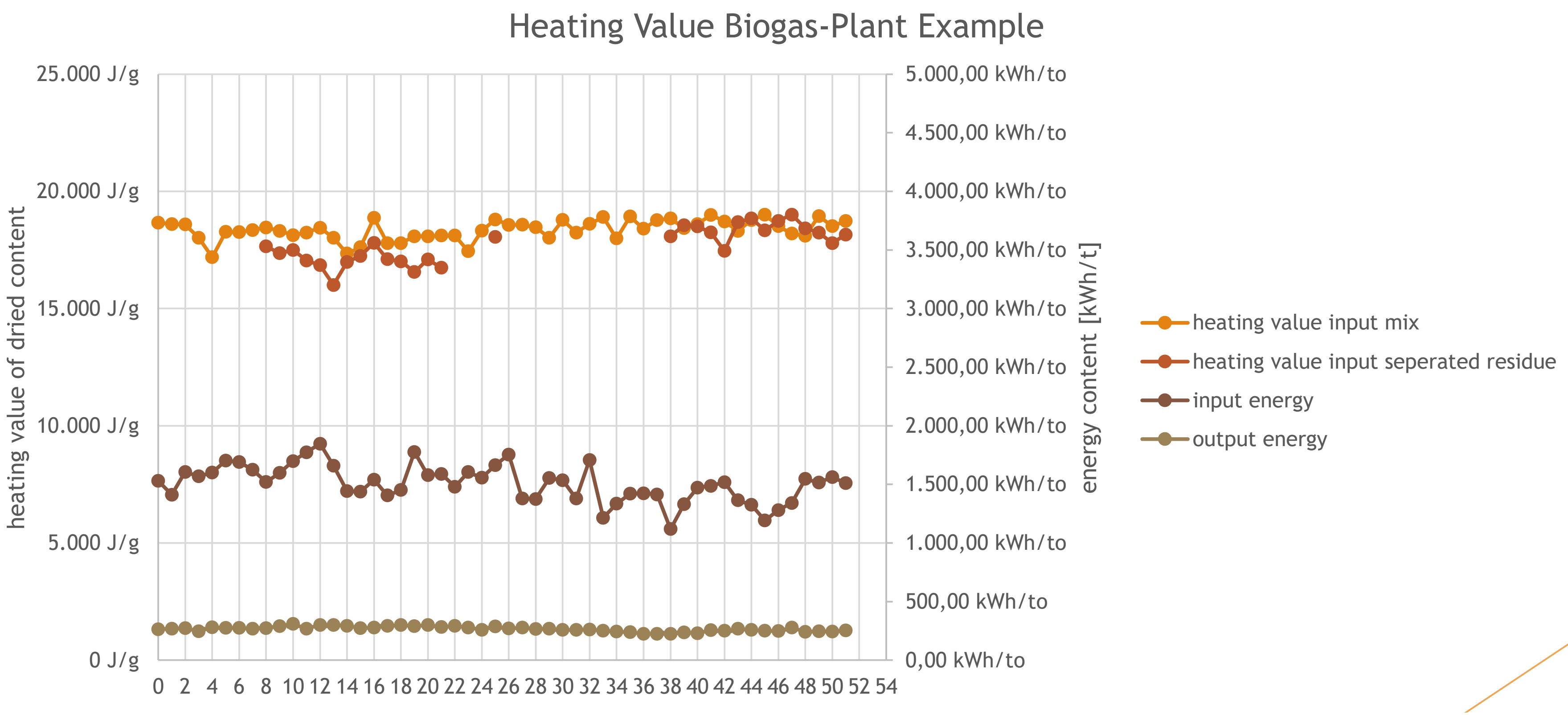

Quelle: Kompetenzzentrum Biomassenutzung, Projektnummer: 14034

average efficiency	Min.	Max.	Standard deviation
82,22%	78,95%	84,84%	1,71%

Rain Water influence – Plant Example

Rainwater:						
de.climate-data.org/location/22078/						
07.12.2016, 15:18h						
Average:				Area: 5.500 m^2 Silo + 620 m^2 Ways		
826 l/m^2						
	Quantity per area:	Area:	Quantity:			
Jan	70 l/m^2	6.120 m^2	428.400 l	428 m^3		
Feb	42 l/m^2	6.120 m^2	257.040 l	257 m^3		
Mrz	55 l/m^2	6.120 m^2	336.600 l	337 m^3		
Apr	50 l/m^2	6.120 m^2	306.000 l	306 m^3		
Mai	57 l/m^2	6.120 m^2	348.840 l	349 m^3		
Jun	62 l/m^2	6.120 m^2	379.440 l	379 m^3		
Jul	81 l/m^2	6.120 m^2	495.720 l	496 m^3		
Aug	81 l/m^2	6.120 m^2	495.720 l	496 m^3		
Sep	80 l/m^2	6.120 m^2	489.600 l	490 m^3		
Okt	80 l/m^2	6.120 m^2	489.600 l	490 m^3		
Nov	90 l/m^2	6.120 m^2	550.800 l	551 m^3		
Dez	78 l/m^2	6.120 m^2	477.360 l	477 m^3		
			Total:	5.055 m^3		
Adoption: Water is pumped into the system and no separation between rain- and contaminated surface water is done						

Retention time Distribution – Plant Example

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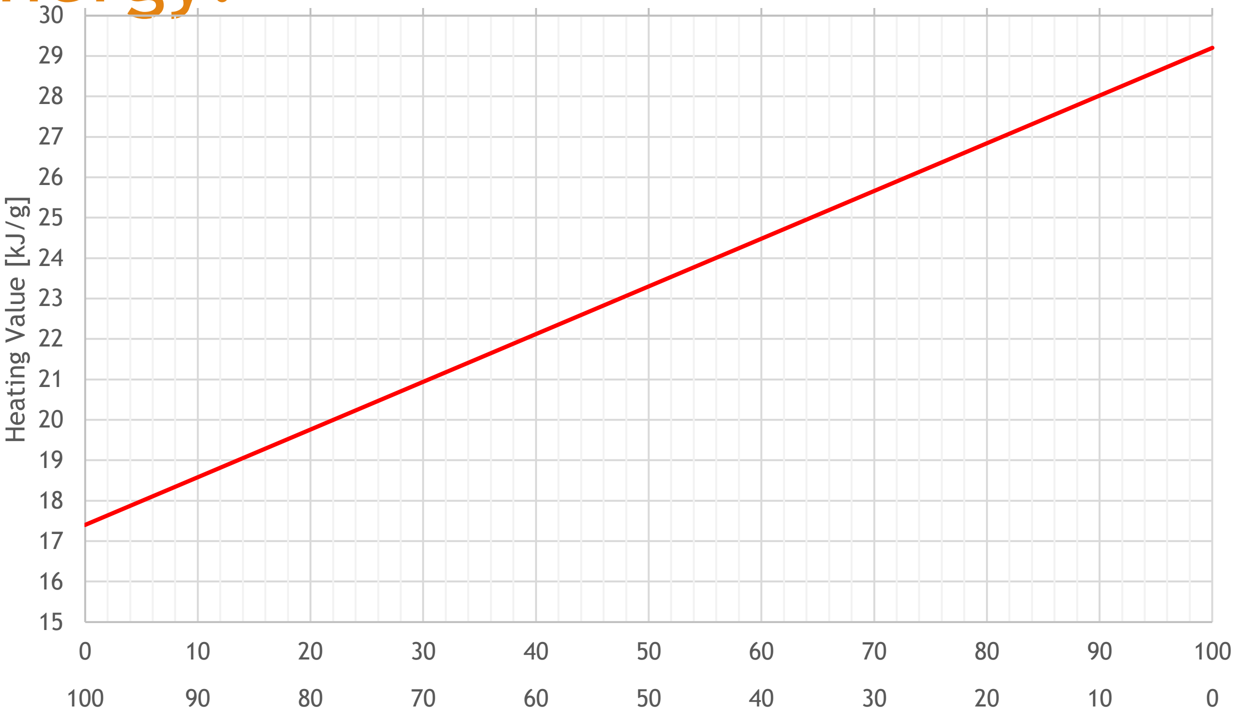
Month	Input-Material	Rain-Water	Leachate-Water	Retention time F1 and F2	Retention time of fermenters	Total retention time of fermentative system
Mai	2.046,52 to	349 m³	0 m³	38,20 d	70,03 d	101,86 d
Jun	2.267,39 to	379 m³	0 m³	34,57 d	63,38 d	92,19 d
Jul	1.978,02 to	496 m³	0 m³	36,99 d	67,81 d	98,64 d
Aug	1.898,21 to	496 m³	0 m³	38,22 d	70,07 d	101,92 d
Sep	2.535,64 to	490 m³	466 m³	26,21 d	48,05 d	69,89 d
Oct	2.439,16 to	490 m³	466 m³	26,95 d	49,42 d	71,88 d
Nov	2.327,09 to	551 m³	0 m³	31,79 d	58,29 d	84,78 d
Dez	2.196,90 to	477 m³	0 m³	34,22 d	62,73 d	91,24 d
Jan	2.038,27 to	428 m³	0 m³	37,09 d	68,01 d	98,92 d
Feb	2.300,03 to	257 m³	0 m³	35,78 d	65,60 d	95,42 d
Mrz	2.356,08 to	337 m³	0 m³	33,98 d	62,30 d	90,62 d
Apr	2.351,86 to	306 m³	0 m³	34,43 d	63,11 d	91,80 d

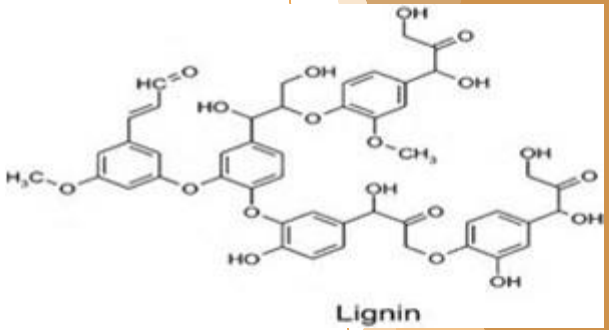
average retention time	Min.	Max.
90,76 d	69,89 d	101,92 d

Status and Limits

- Complete mass and energy balances are not possible for now, due to the mentioned correction factors
- To create these balances, general correction factors for each type of biogas plants have to be found
- The method is only valid for biogas plants, using energy crops and manure as input. It is not valid for waste treatment plants
- An extension of the method can be the calculation of degradable energy to show the residual energy potential of the used input materials
- To see the influence of input material changings and changing of the process management, the time series should be at least three times the hydraulic retention time

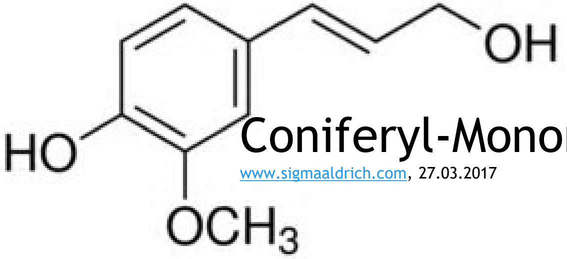
Objectives – Heating Value of Lignin for Determination of the Residual Degradable Energy?





Quelle: www.hdimagelib.com, 23.03.2017

Quelle: www.ika.com, 23.03.2017

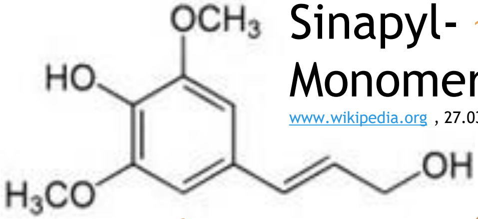


Coniferyl-Monomer

www.sigmaaldrich.com, 27.03.2017

Coumaryl-Monomer

www.wikipedia.org, 27.03.2017



Sinapyl-Monomer

www.wikipedia.org , 27.03.2017

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Conclusions – Time Series analysis with calorific investigations for Biogas Plants

- We can conclude:
  - Independent investigation Method for determining the efficiency of Biogas Plants
  - System boundary includes the whole Biogas Plant
  - Constant delivered samples of In- and Ouput are mandatory
  - Correction factors for balancing are neccessary
  - Time Series should be at least three times the hydraulic retention time

  - The method is (for now) only valid for Biogas Plants using energy crops and / or manure
  - To describe the degradable residual energy Lignin could be the indicator

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