Gasification of digestates and nutrient recycling

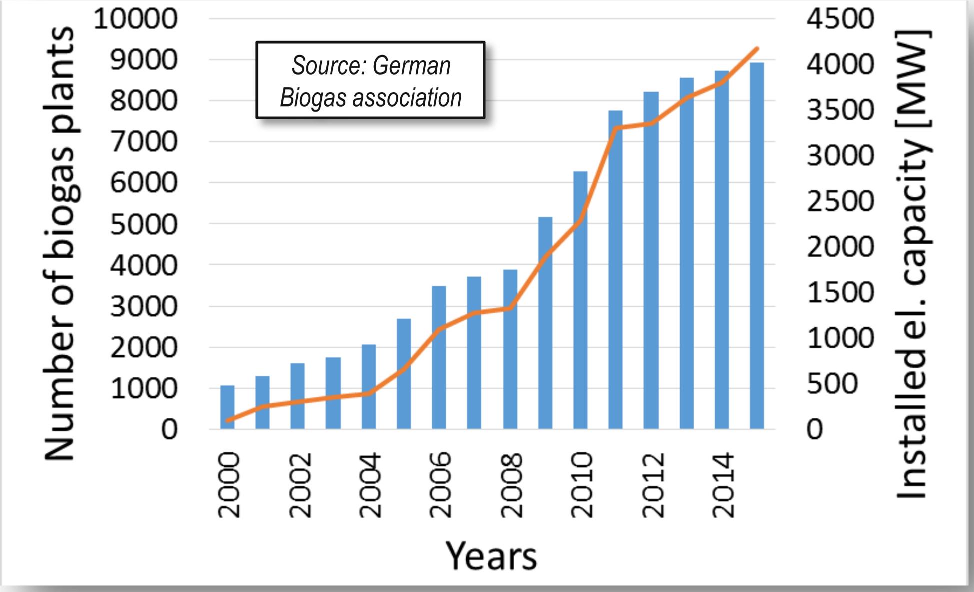
Prof. Dr. Thomas Kienberger

DI Mag. Kerstin Schopf

Source: Ökobit Biogas

Source: Fraunhofer Umsicht

Trend of development of biogas plants in Germany



Today in Germany:

- around 75.000.000 t p.a. of biogas-digestates (10% dry-matter)

Potential?

- Biogas-digestates: $7.5\ Mt_{dry} \cdot 15\ \frac{MJ}{kg} \approx 31\ TWh$

At 8000 h of operation:
- *3,9 GW for Biogas-digestates*

Introduction

Today's use of digestates?

- Mostly local use as ecological fertilizer
- But…

1. Local Oversupply

   Transportation costs exceed fertilizer value if distance is above 10km

   Source: www.fnr.de

2. Disposal bans

   in overfertilized regions (NO_3^- - problem)

3. Poor conversion-efficiency of digestion-processes

   - only around 50% of feed's calorific-value gets converted in digestion
   - Most nutrients remain in the ash, also after subsequent thermal conversion

But…Can they still be incorporated by the soil?

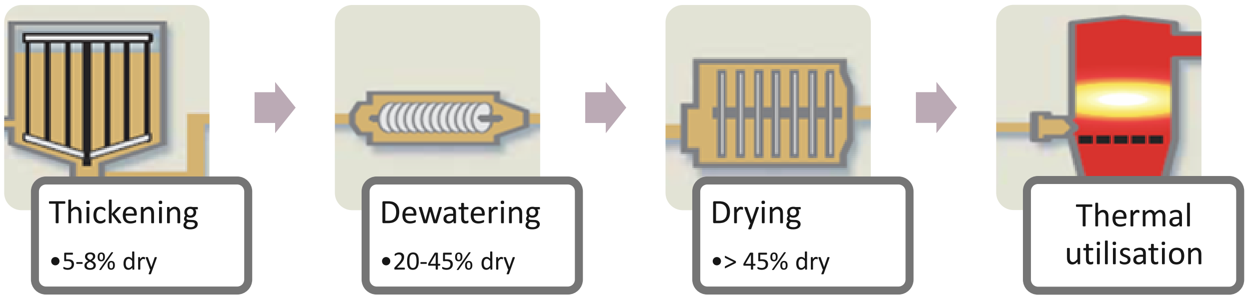
Potential?

- Biogas-digestates: $7.5\ Mtdry \cdot 15\ \frac{MJ}{kg} \approx 31\ TWh$

At 8000 h of operation:
- *3,9 GW for Biogas-digestates*

Fuel assessment

- Fuel preparation: for economic use drying and dewatering is necessary. Due to low-calorific-values: **drying to 10% Water-content**



Both digestates are mize- and grass-silage based

	Water content [%]	Ash content [%]	Calorific Value [MJ/kg] Gross	Calorific Value [MJ/kg] Net
Biogas-digestate 1	9.2	18.3	17.3	15.8
Biogas-digestate 2	9.9	14.6	16.4	15.0
Pinewood (with bark)	12.0	3.0	18.5	16.3

Source: Kratzeisen et al (2010)

- Energetic point of view (of dry digestates): Net Calorific values of biogas-digestates can be compared with wood.
- High ash-contents: Digestates require challenging ash-handling

Fuel assessment

Ash characteristics

	Temperature in °C		
	Softening	Hemisphere	Flow
Biogas-digestate 1	1.090	1.290	1.320
Biogas-digestate 2	1.110	1.150	1.390
Pinewood (with bark)	1.430	1.600	1.600

Source: Kratzeisen et al (2010)

Thermal-Conversion-Requirement: *Combustion- respectively Gasification- temperatures **NOT** higher than 1000°C*

- Inhomogeneous fuels: Compositions vary widely

Gasification of digestates

Motivation for Gasification:

In comparison to combustion plants:

- Lower investment-costs
- Higher electrical efficiencies

Dried Biogas-digestates plant sizes

- some 100 kW for on-site gasification
- Low MW-range for plants with digestate-logistics

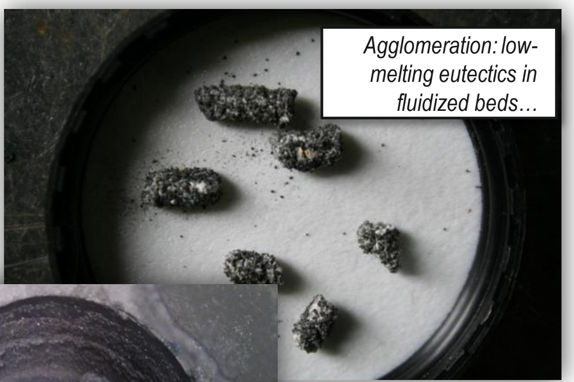
Today, No „market-ready" systems exist
All concepts are maximally in the stage of pre-commercialization

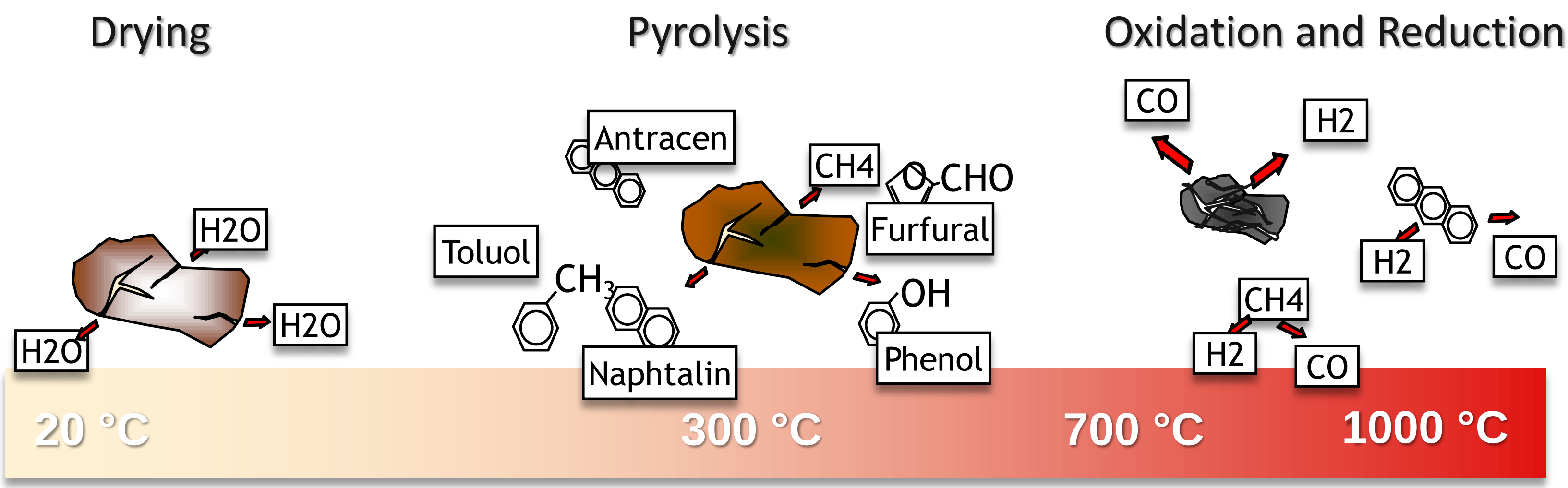
Major hurdle

- Reaching low tar-contents at the low gasification temperatures needed to avoid ash-slagging.

Also challenging

- Ash-stream handling...
- Gas-cleaning
- Corrosion related issues





Solution BFB-Gasification?

Optimal temperature-control possible, but..

Continuous backmix-reactor:
Systematically high tar-contents between 1-10g/Nm^3

Major hurdle

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Also challenging

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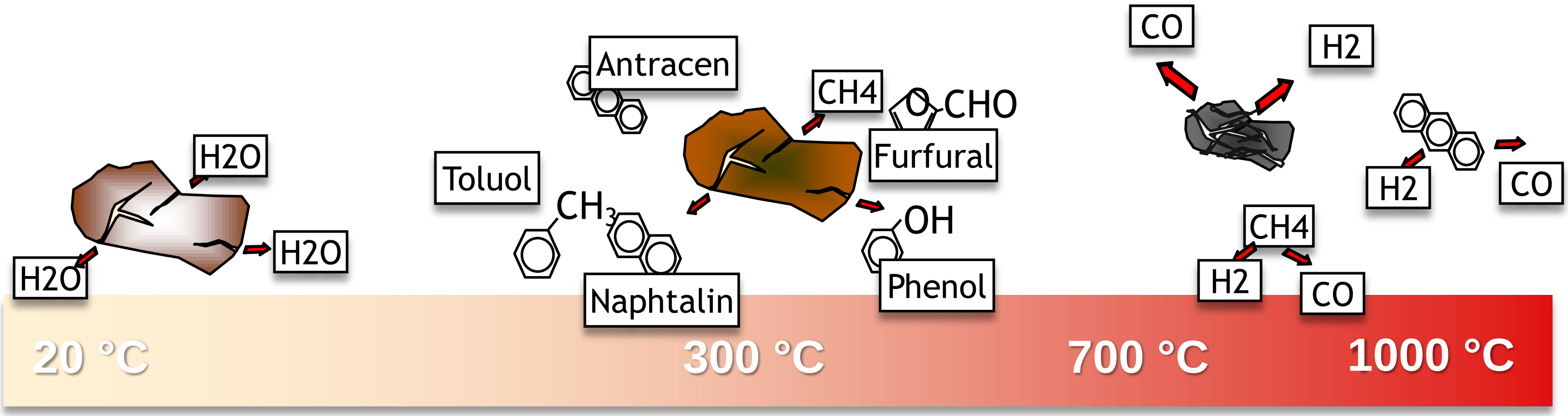
Agglomeration: low-melting eutectics in fluidized beds…


Slagging: 2h of operation..

Drying Pyrolysis Oxidation and Reduction



Solution **Staged-Gasification?**

Oxidation of low-temperature pyrolysis-products, Char-coal reduction below ash-melting temperatures

Challenging in terms of plant-design, but...
Why not?

Major hurdle

- Reaching low tar-contents at the low gasification temperatures needed to avoid ash-slagging.

Also challenging

- Ash-stream handling...
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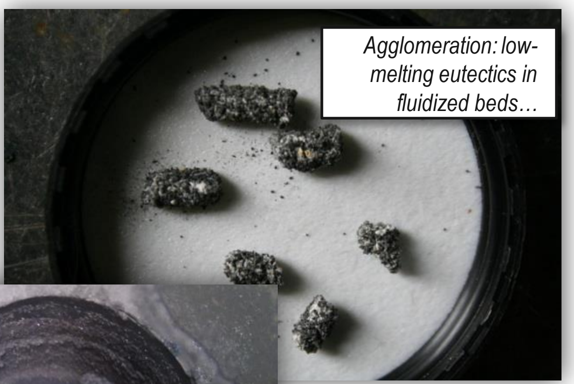
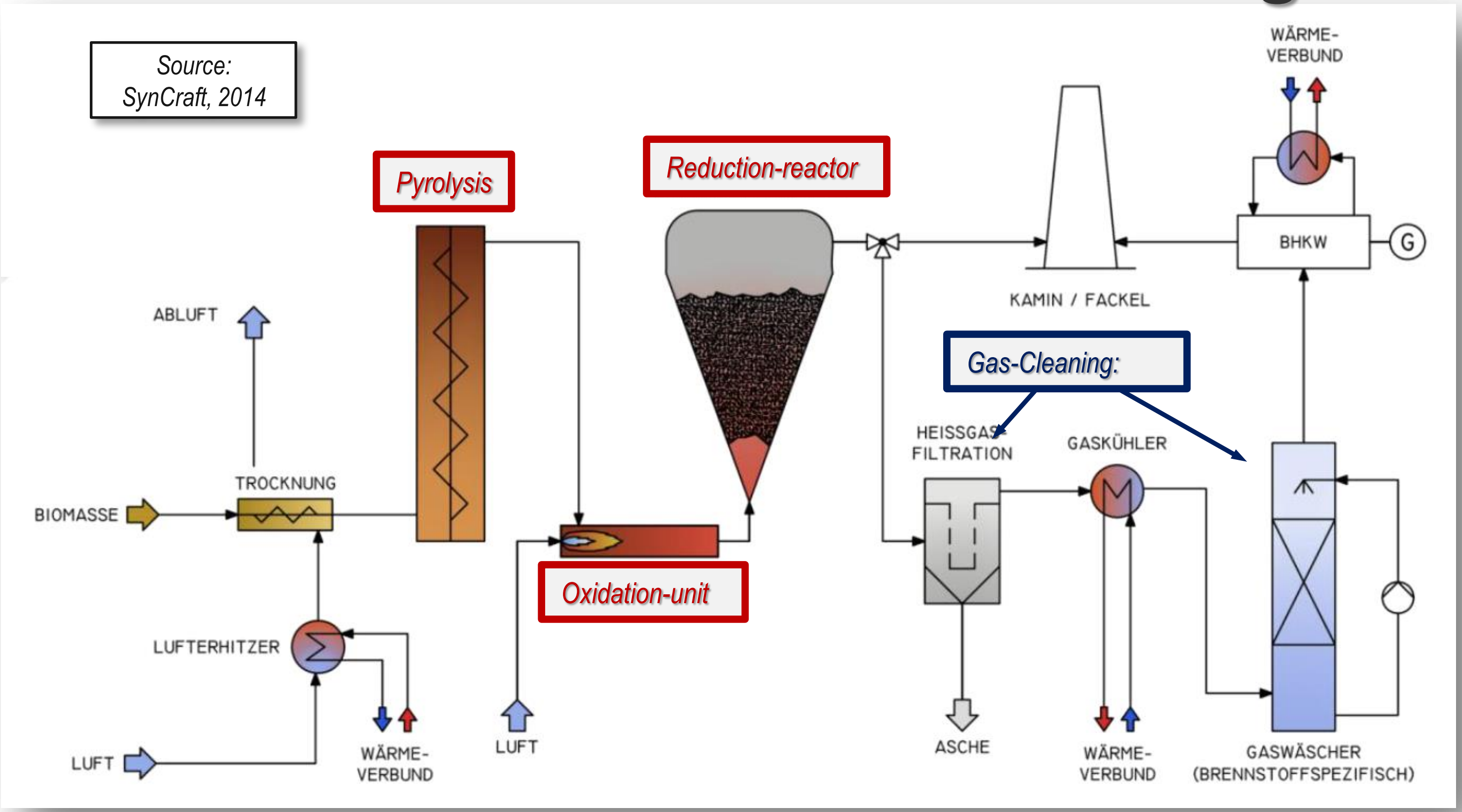


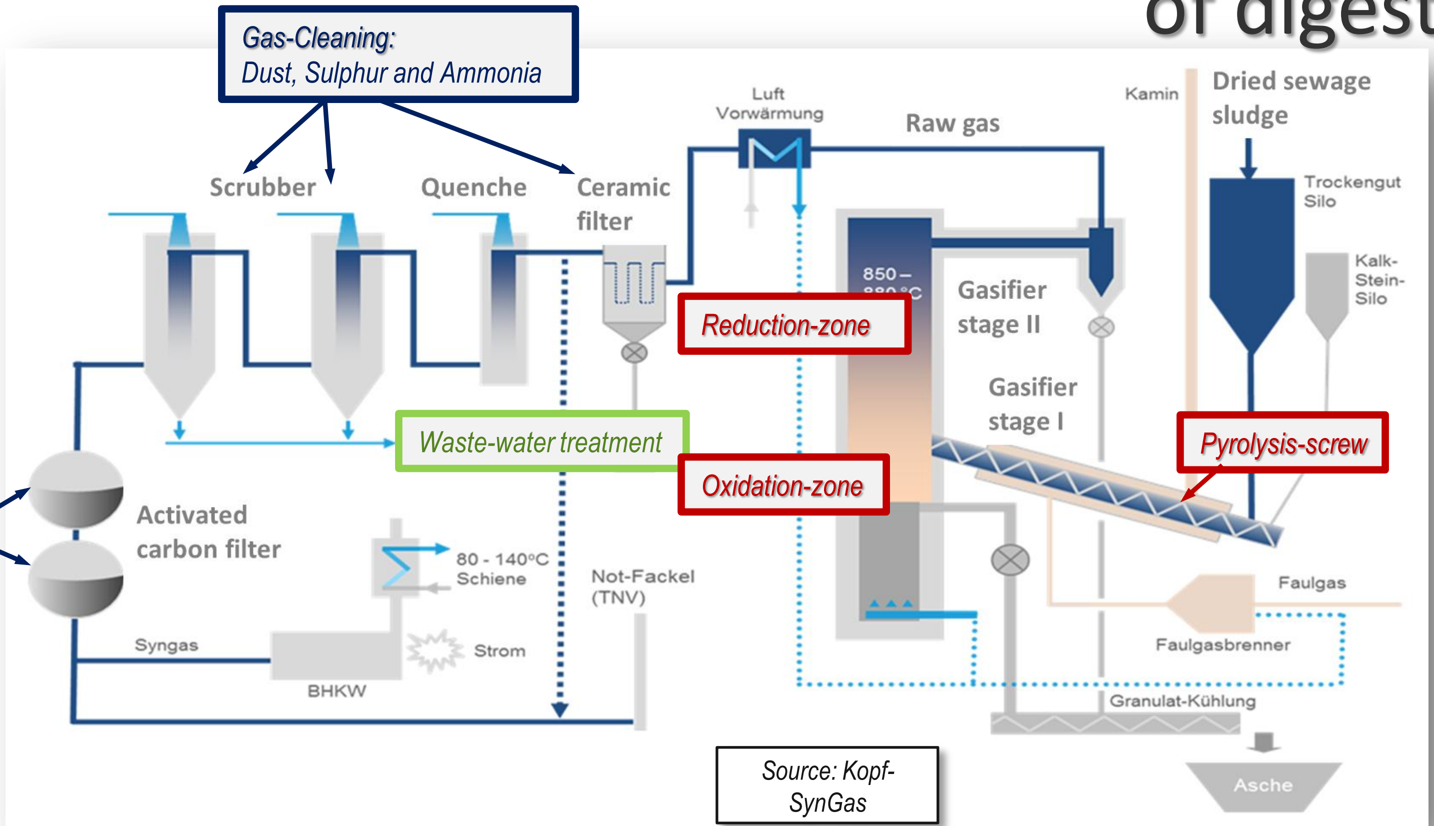
Staged gasification of biogas-digestates



Syncraft → CraftWERK

- screw-pyrolysis → pyrolysis gas oxidation → char reduction in expanded bed reactor
- Fuel: pelletized biogas-digestates → 2014, positive tests, Craftwerk700 fits to 500 kW biogas-plant

Staged gasification of sewage-sludge



Kopf SynGas-plant in Koblenz (D)

- New concept: screw-pyrolysis → pyrolysis gas oxidation → char reduction in ash-bed
  aim: Low-tar contents.
- 4000 t_{Dry} p.a. → around 1 MW nominal fuel capacity → around 350 kW_{el}
- Concept can be adaped for the use of biogas-digestates also

EVT Energieverbundtechnik

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Nutritional requirements

These basic nutrients are generally available to plants in sufficient quantities simply through air, soil, & water

BASIC NUTRIENTS

- 6 C – CARBON
- 1 H – HYDROGEN
- 8 O – OXYGEN

Primary macronutrients (NPK's) are the primary foci of most traditional fertilizer application programs.

PRIMARY MACRONUTRIENTS

- 7 N – NITROGEN
- 15 P – PHOSPHOROUS
- 19 K – POTASSIUM

Secondary macronutrients and micronutrients are often grouped together for classification and identification. While they are not generally the foci of fertilization programs, they are absolutely essential for successful and healthy plant growth.

SECONDARY MACRONUTRIENTS

- 20 Ca – CALCIUM
- 12 Mg – MAGNESIUM
- 16 S – SULPHUR

MICRONUTRIENTS

- 26 Fe – IRON
- 25 Mn – MANGANESE
- 30 Zn – ZINC
- 29 Cu – COPPER
- 5 B – BORON
- 42 Mo – MOLYBDENUM
- 17 Cl – CHLORINE

While not widely considered to be essential components of plant nutrition, these elements are known to be required by certain plant types in certain environmental circumstances.

OTHERS

- 14 Si – SILICON
- 27 Co – COBALT

Color-Coding Key: Elemental Classifications

- NONMETALS
- ALKALI METALS
- ALKALINE EARTH METALS
- POOR METALS
- TRANSITION METALS

Source: sulvaris, 2016

Fuel assessment

Element	Unit	Biogas-digestate 1	Biogas-digestate 2	Pinewood (with bark)
C	wt%	45.3	43.2	49.7
N	wt%	2.9	1.5	0.13
O	wt%	28.4	35.9	43.3
H	wt%	5.2	5.5	6.3
P	wt%	1.3	1.1	0.03
S	wt%	0.9	0.3	0.02
K	wt%	1.4	1.6	0.1
Cl	wt%	0.84	0.27	0.01
As	mg/kg	0.93	0.54	0.48
Cd	mg/kg	0.29	0.15	0.23
Cr	mg/kg	13.2	21.5	6.8
Cu	mg/kg	58.8	18.2	3.5
Pb	mg/kg	4.4	0.78	2.17
Hg	mg/kg	0.07	0.04	0.04
Zn	mg/kg	304	125	35

Source: Kratzeisen et al (2010)

- Digestates show considerably higher amounts of nutrients in comparison to wood
- …but also heavy-metals are higher

Nutrient recycling

Ash as fertilizer: differences between gasification and combustion

Source: Pan & Eberhardt (2011)

	Combustion	Gasification
	g/kg dry	
Ca	130.65	75.57
Mg	44.13	7.91
K	129.47	20.33
P	11.76	2.44
Mn	12.32	4.20
B	0.71	0.14

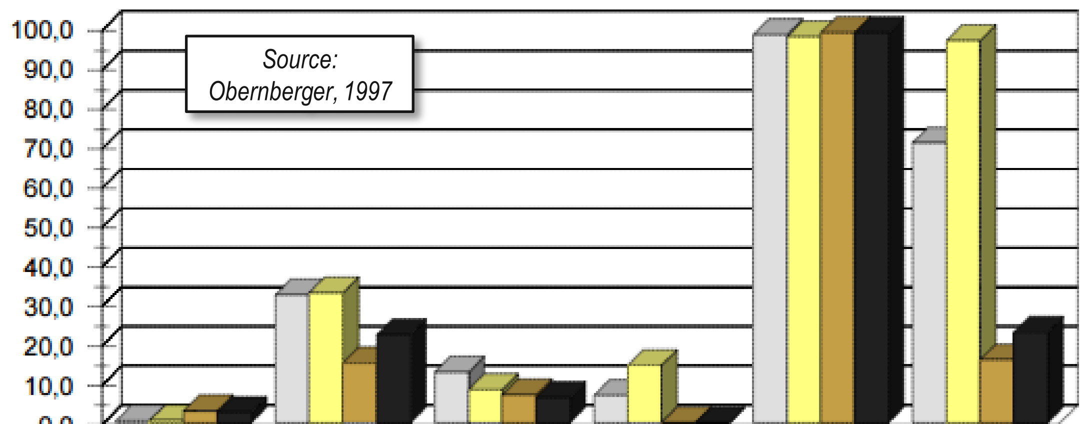
All wood-based data: poor data-base for digestate-ashes

- Differences in elemental concentrations depend mostly on the process-temperature and the systematically high carbon content of gasification Bottom Ashes (ca. 50%)
- Lower P, Mg and K concentration the higher the process-temperatures are
- Both: no Nitrogen

Nutrient recycling

Ash as fertilizer: elutability of nutritions

Elutable content in w% with respect to the overall mass



	Ca	K	Na	P	Cl	S
Straw	0,5	32,5	12,9	6,9	98,5	71,0
Whole plants	0,6	33,0	8,4	14,6	98,0	97,0
Bark	3,0	15,2	7,1	0,0	99,0	16,0
wood-chips	2,6	22,3	6,4	0,0	99,0	23,0

- Generally: higher temperatures and pressures in the thermal process decrease short-time plant-availability
- P is very badly elutable
- Biomass-ashes are therefor considered as a long-time soil-conditioner

Source: *Pan & Eberhardt (2011)*

Nutrient recycling

Ash as fertilizer: heavy metals

	Gasification	German fertilizer act
	mg/kg dry	
As	10.06	40
Cd	4.39	4
Cr	38.51	-
Cu	37.25	70
Ni	47.29	80
Pb	11.83	150
Zn	345.45	1,000

Source: Adam et al (2009)

- Generally: Fine fly-ashes (bag-filter, E-filter) contain high heavy-metal contents (Zn) and must be deposed.
- Coarse biomass-ash (Bottom-ash) normally is within the limits of national fertilizer acts. High heavy metal input due to local conditions must be taken into account.
- Caution: Plants with highly stressed stainless-steel components can emit ashes with to high concentrations of Ni and Cr.

Summary

- For gasification of digestates , promising concepts, based on staged-gasification, exist. Major hurdle is the high ash-content and the low ash-softening temperature.

- Ashes from the thermal utilization of digestates can be used as fertilizer, but they can only be a part of a total nutrient management strategy

Pros

- Often high in P and K
- High Ca concentration possible
- Ash can improve the nutrient balance in soils

Cons

- No Nitrogen
- Only minor short-time plant-availability
- Heavy metal contents
- Gasification ash: Carbon and PAH

Thank you for your kind attention.