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Optimization of anaerobic digestion

by pretreatment, additives and process engineering

Biogas Process Optimisation, Workshop 18th April 2013 in Bern / Ittigen

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Why and how to pretreat?

Why?

- 35% conversion efficiency of cattle manure is low
- 13% energy efficiency of biomass to electricity is weak

How to pre-treat?

- Mechanical pretreatment
- Chemical-Physical: Heat, ultrasonic, microwave, electrokinetic (BioCrack), acid, alkali, high-pressure steam expansion, ozone treatment
- Biological: Hydrolytic enzymes, Fungi, microorganisms

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→ Mild methods preferred

Methods are abundant.
Finding the suitable pretreatment method

- Powerful enzymes for lignocellulose degradation to produce US biofuels (Genzyme)
- Ultrasonic treatment: 50 % more biogas from sewage sludge (Barber 2005)
- Ozone treatment of lignocellulose in manure (Sugimoto et al. 2009)
- Enzymatic digestion of switchgrass and manure (Wen 2004, 2008)
- Good results with ultrasonic treatment of fibre biomass (Chen 2008)
- German technology to pulverize every Nawao substrate (energy plants)
- Novel bacteria for hydrolysis and biogas production from maize silage

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Swiss Substrates

Theoretical potential / used

(in PJ)

- **Cattle manure** 47 / 0.6
- Green waste 10 / 1.1
- Food industry 4.4 / 0.5
- Sewage sludges 1.7 / 1.3

Goal: we want more gas!

We focused on substrates with mass potential in Switzerland

Manure and its fractions / sewage sludge / green waste

We focus on substrates with <u>incomplete degradation</u>

Green Waste / cellulose substrates / protein substrates

- ➔ We provide an <u>independent</u> overview of the effectiveness of chemical - physical pretreatment and their economic potential.
- ➔ We create a basis that allow an assessment of the use of enzymes in industrial scale.
- ➔ We provide a systematic comparison as basis for decision of new product development.

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Example: Hydrolytic enzymes

- Catalyze reactions that would otherwise occur very slowly or not at all.

Fig. 1: Grass silage incubated with and without hydrolytic enzymes (cellulase + hemicellulases) for 15 h at 50 °C.

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Summary: 30 % increase is feasible

- ✓ Thermal pretreatment steps are efficient, but must be adapted to the substrate. 15 - 20% higher gas yield is achievable.
- ✓ Enzymatic effects are in the range of 5 % more gas yield, but they justify the use of enzyme mixtures barely.
- ✓ Enzymes are proteins and not stable in a microbiologically active anaerobic environment.
- ✓ By combination of heat and enzymes 25 - 30% gas yield increase is technically feasible.
- ✓ If the economy is based solely on cost - benefit from biogas, the profit is marginal. With beneficial side-effects (residual heat use, sanitation, reducing viscosity) pretreatment may be beneficial.
- ✓ Ecological footprint of pretreatment was not investigated here.

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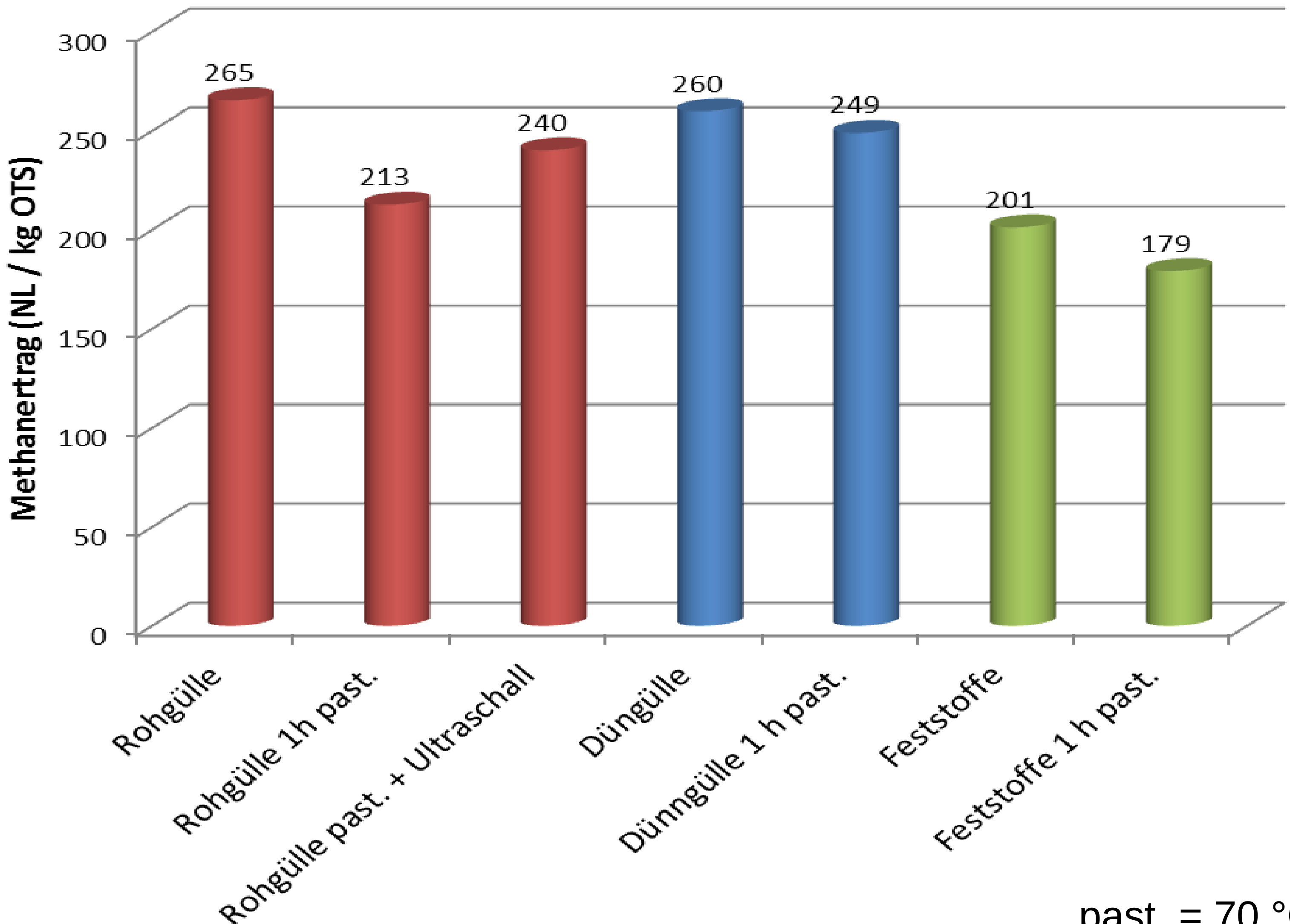
Downside trends are possible

Example of cow manure fractions



past. = 70 °C

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Electronic biogas production recording

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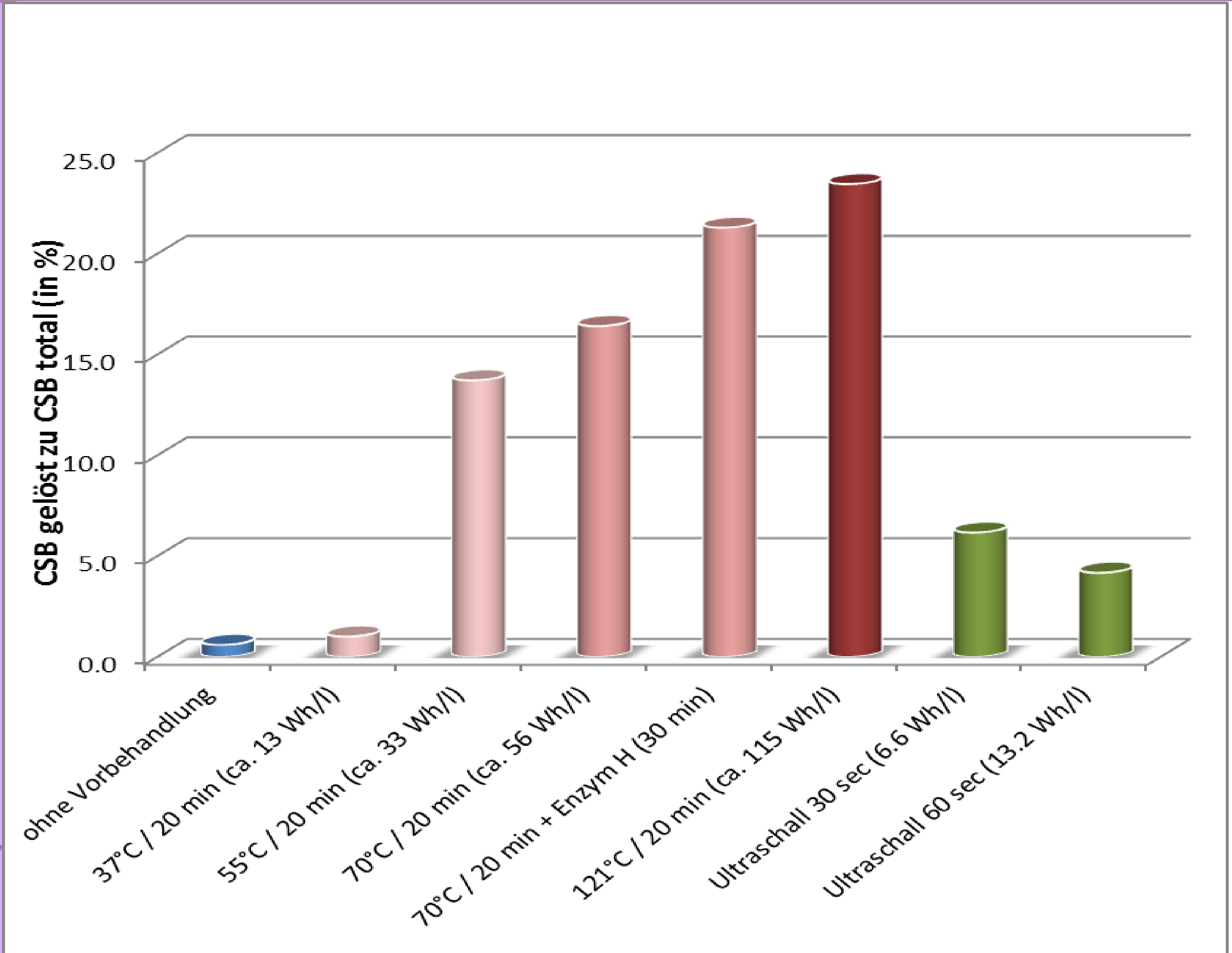
Physical pretreatments are often not worth the energy that they need!



Sewage sludge pretreatment

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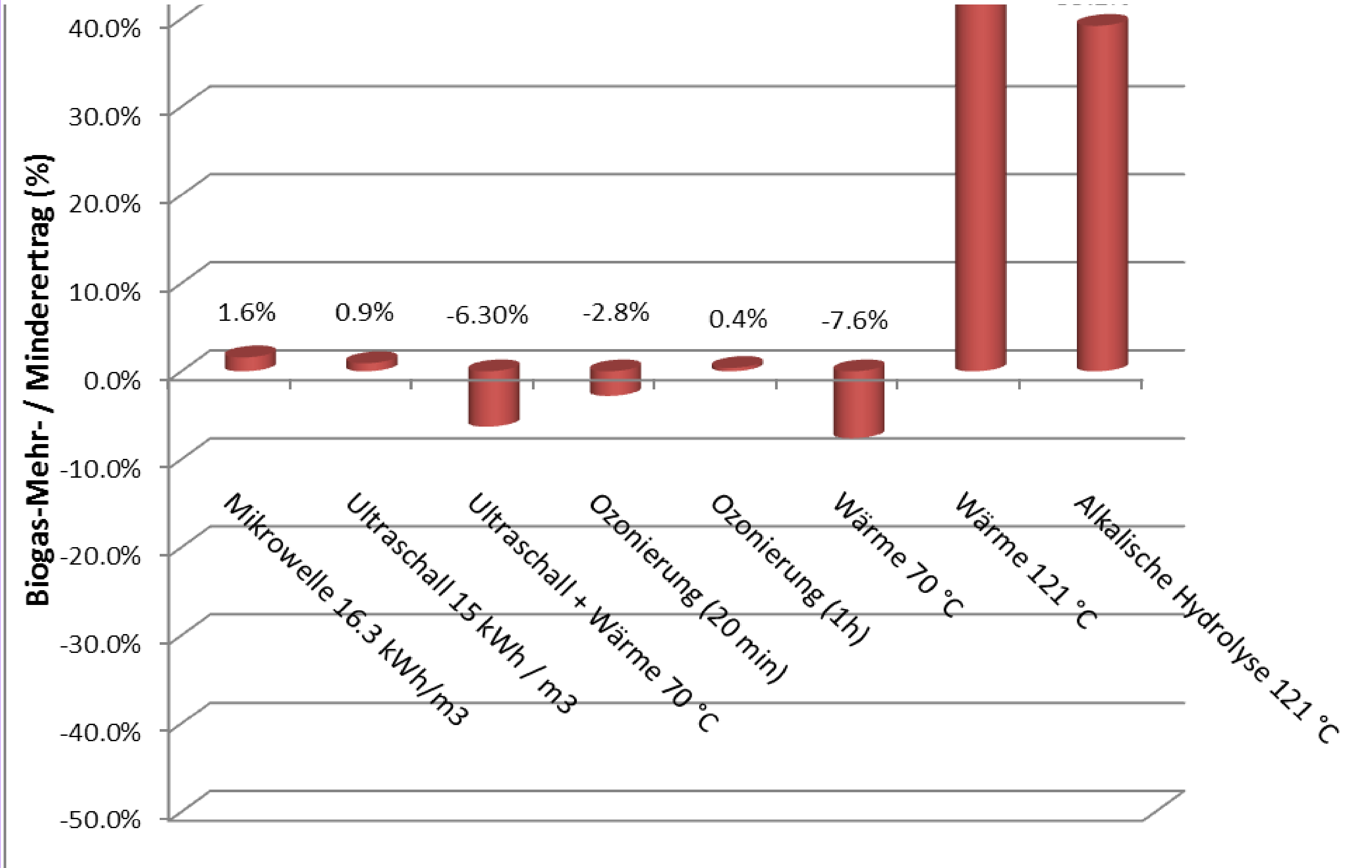
Cattle manure is resistant against mild physico-chemical methods

Physico-chemical pretreatment of cattle manure



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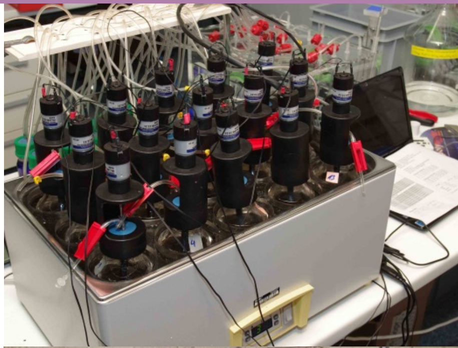
Conclusions
physico-chemical pretreatment

- High-temperature pretreatment at 70 ° C - 121 ° C show a lasting effect: they not only generate soluble material, but also lead to increased degradation
- Other physical pretreatments, such as ultrasonic treatment, showed mainly positive effects with cellular substrates i.e. with sewage sludge
- Cattle manure and their fractions showed extreme resistance to all chemical, physical and mechanical pretreatments. With mild methods, increased gas yield was not realized.
- The achievable energy conversion due to improved digestion and degradation usually does not cover the energy required for pretreatment.
- In thermal pretreatment steps, the heat must be recovered.



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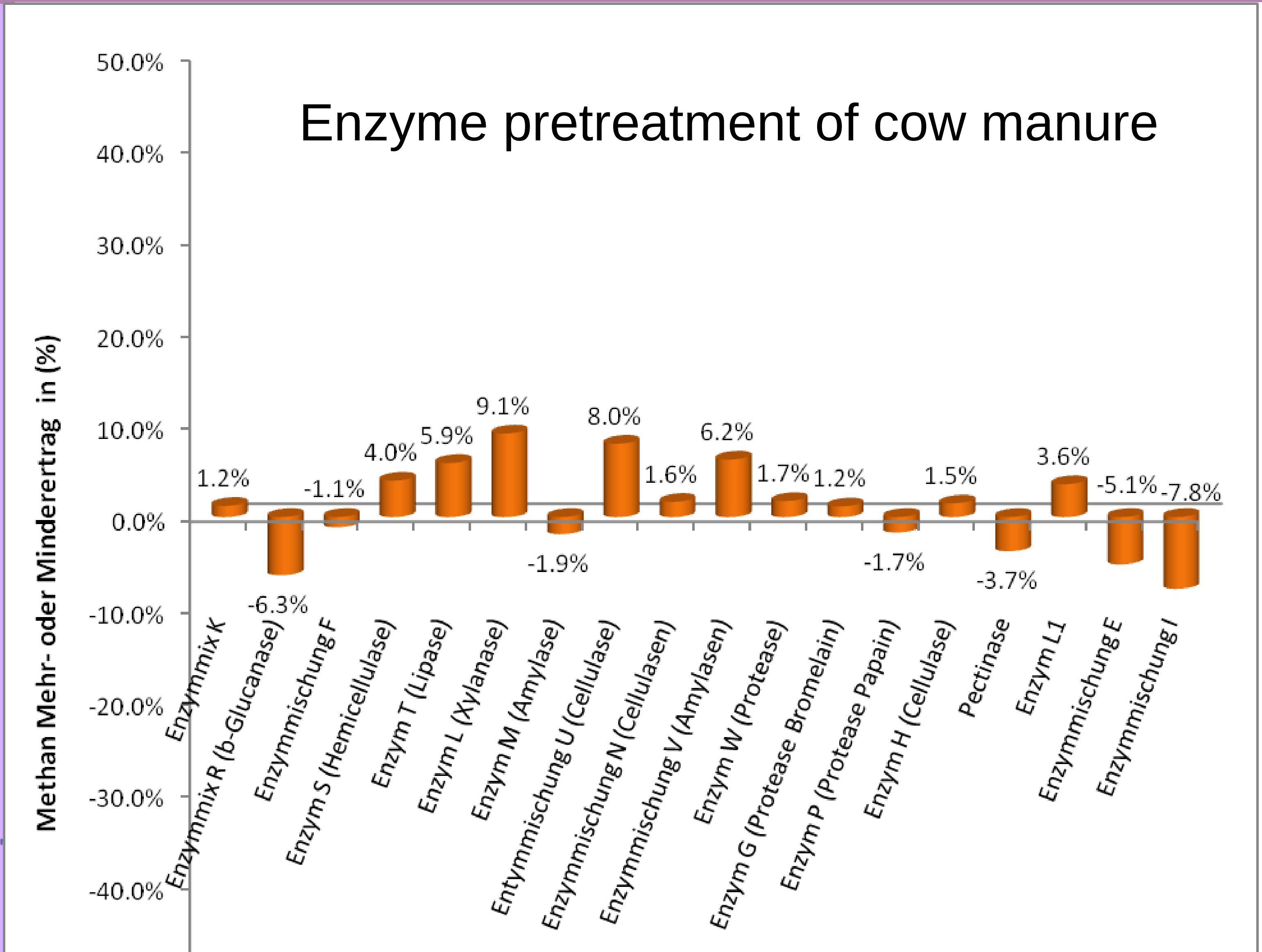
Also valid for enzyme treatment: Cattle manure is a resistant substrate



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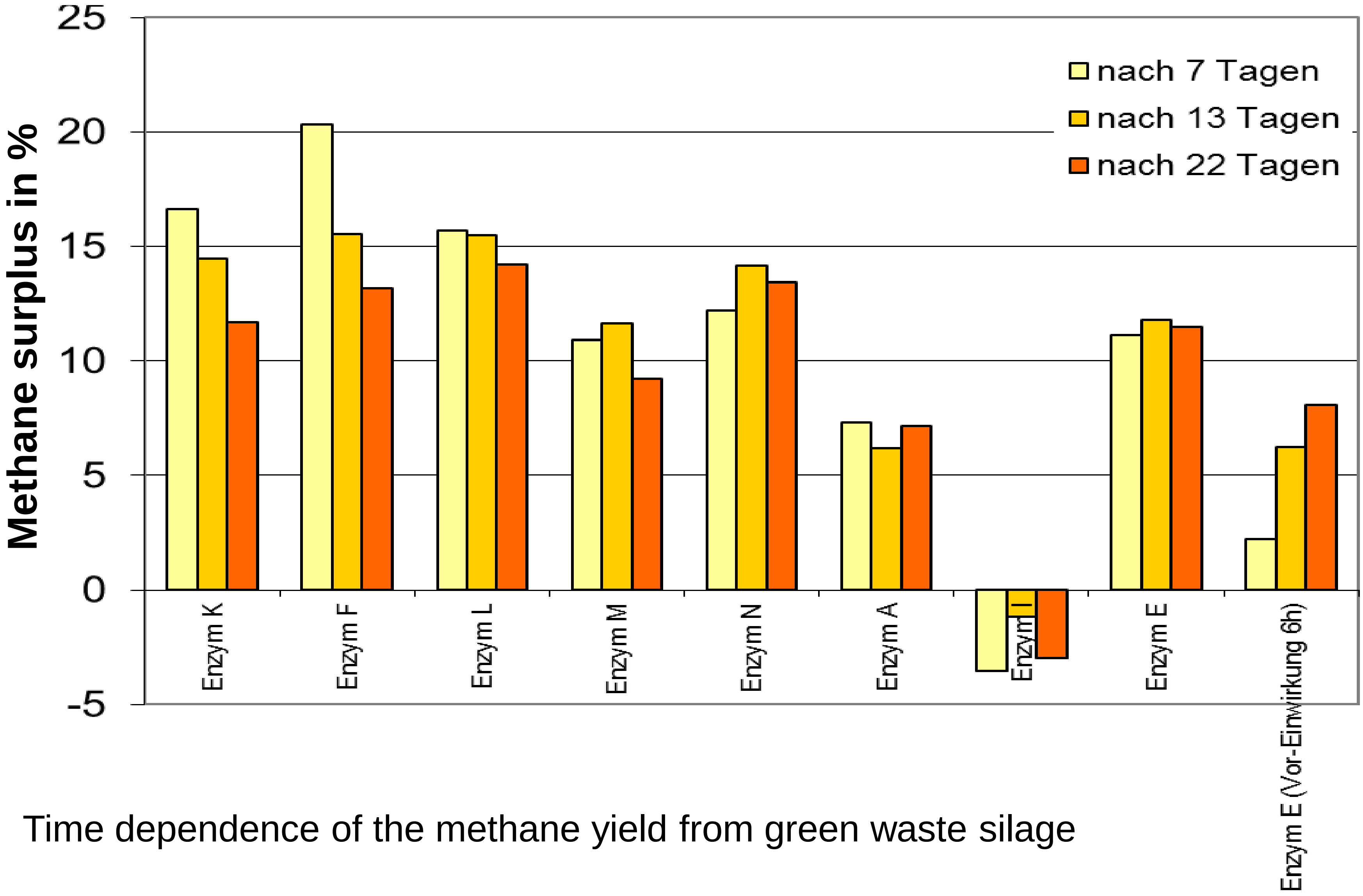
Enzymes can do it better, but the effect is not necessarily maintained!



Time dependence of the methane yield from green waste silage

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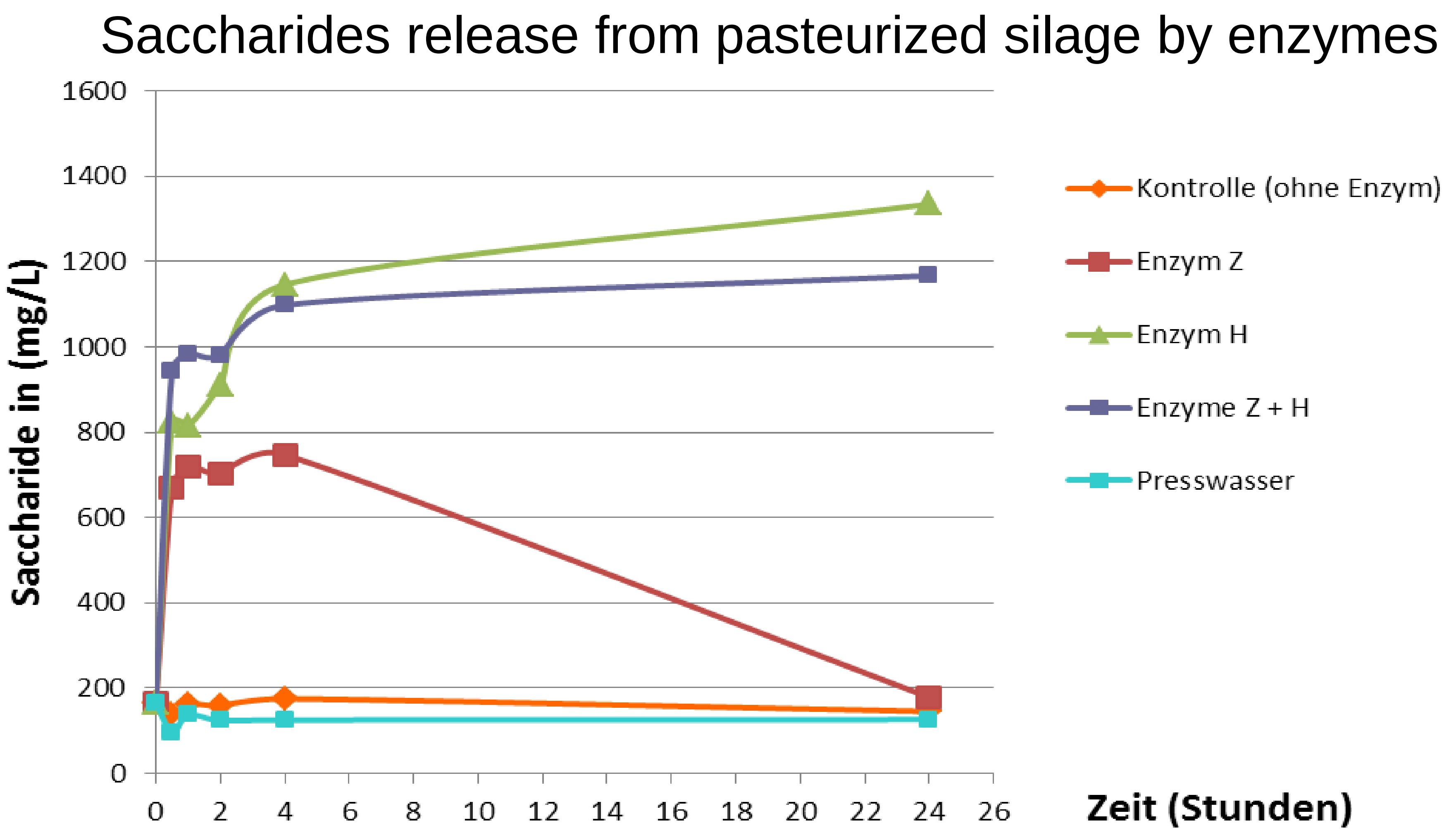
Enzymes are unstable in the fermenter!



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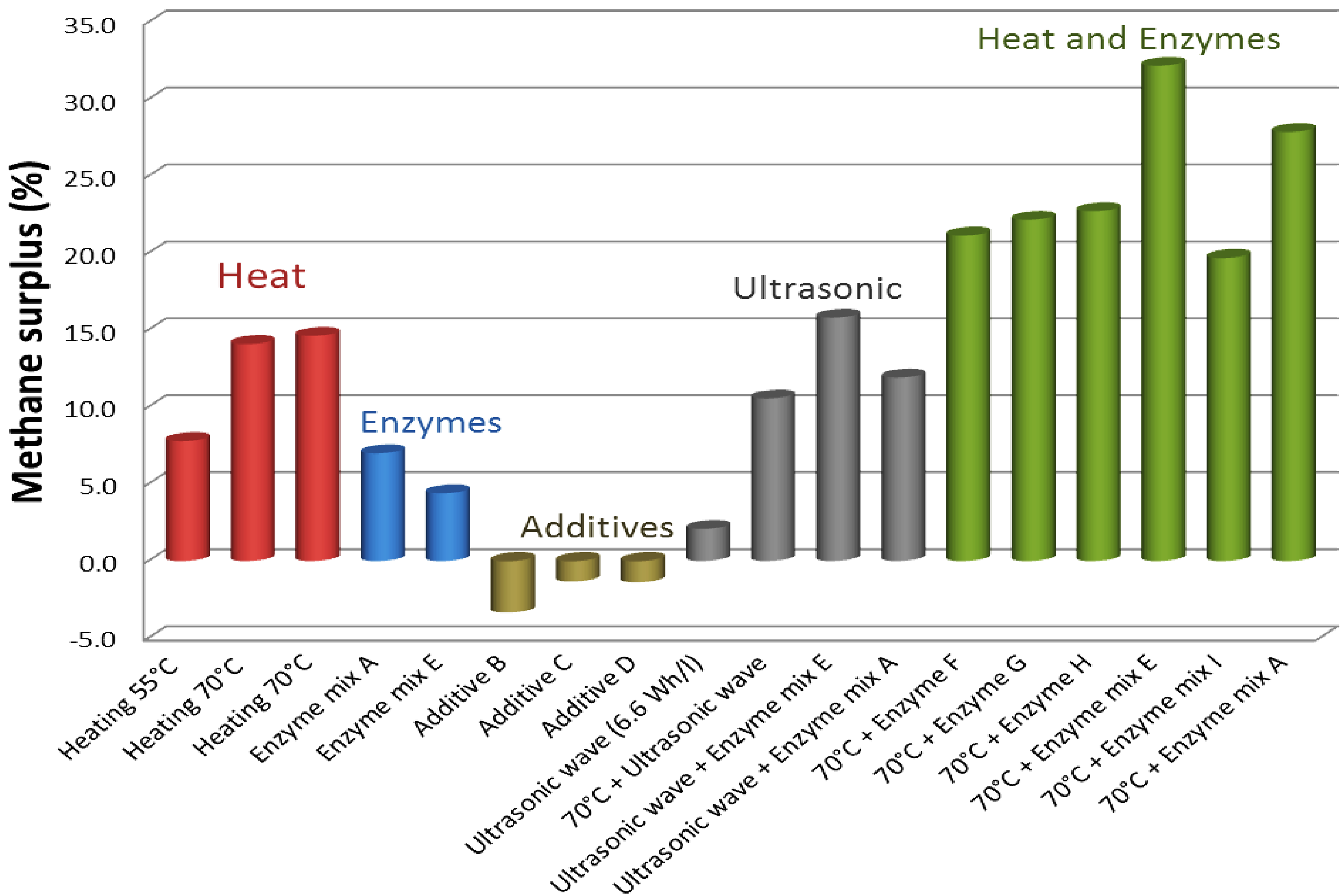
Conclusions enzymes

- Commercially available enzyme mixtures are optimized for Nawaro and therefore not really suitable for organic waste substrates.
- Cattle manure and their fractions are very resistant to enzymatic digestion.
- Cellular and cellulose-containing substrates are suitable for the use of enzymes. 15 – 20 % increased methane yield is possible.
- The sales returns from additional methane by enzymes barely covers the costs.
- Enzymes and enzyme mixtures are not stable in biogas plants. Their activity is limited to hours, then they become inactive, or they are broken down by the anaerobic population.
- For the specific use of enzymes in the biogas process, a separate stage with optimized conditions is essential (pH, temperature, sterile).

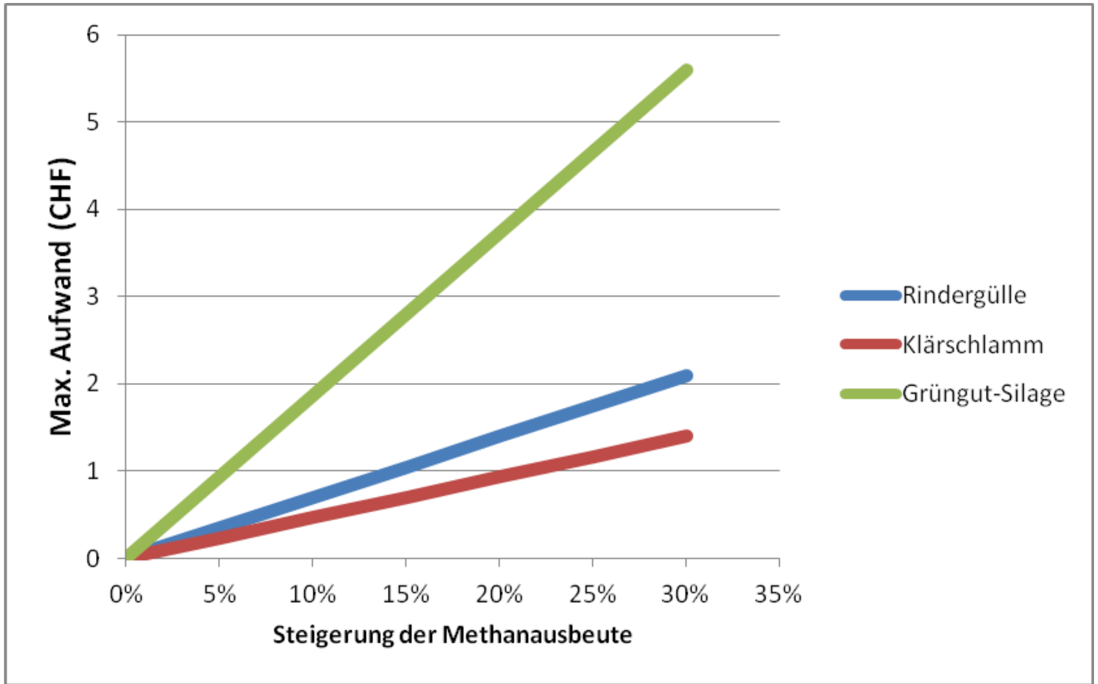
Fazit: 1/3 more gas is feasible

Results from sewage sludge treatment



Pretreatment yes, but for what price?

- The benefits should exceed the costs by a factor of 3
- e.g. for 10 % more methane yield from cow manure the cost for pretreatment must not exceed 0,35 CHF / ton.
- Use heat when it is free (the higher the temperature the better)
- Hygienisation by heat is only profitable with high-energy substrates



we continue….

- Process engineering: For manure fractions (liquid/solid) selected pretreatment methods are applied on a larger scale and in separate compartments. Separation of hydrolysis from methane reactor.
- The possibility of inclusion of long-term medium-level heat is examined.
- The effect of heat on digestion and the methane yield from food waste is described.
- The electrokinetic disintegration of municipal sewage sludge and other biogas substrates is being carried out on a pilot plant scale.
- Life cycle assessment of pretreatment methods is needed.

Pretreatment has potential!

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