Reducing the effluent nutrient concentration of municipal wastewater treatment plants using microalgae and considering further biomass application

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Agenda

- Problem P-removal - New requirements in Hesse
- Research project: reduction of the effluent concentration from wastewater treatment plant Rotenburg
- Results microalgae/nutrient removal
- Methane potential tests from algal biomass
- Conclusions
- suggesting for potential collaborative research

New requirements in Hesse:

WWTP-class of size	Design	**German** Wastewater Regulations (AbwV, Anhang 1 1997 / 2004 / 2017)	Program of Measures **Hesse** acc. EU Water Framework Directive **2015 – 2021**	
		P_{tot}	P_{tot}	o-PO_4-P
	[PE]	[mg/l]	[mg/l]	[mg/l]
1	< 1.000	-		
2	1.000 - 5.000	-	2,0 [1)] 1,0 [4)]	
3	5.001 - 10.000	-	2,0 [1)] 1,0 [4)]	
4	10.001 - 100.000	2,0 [1)]	0,7 [1)] 0,5 [2)]	0,2 [3)]
5	> 100.000	1,0 [1)]	0,4 [1)] 0,2 [2)]	

[1)] Monitoring value 2h-sample
[2)] Monthly average 24h-sample
[3)] Limit value 24h-sample
[4)] Target value yearly average

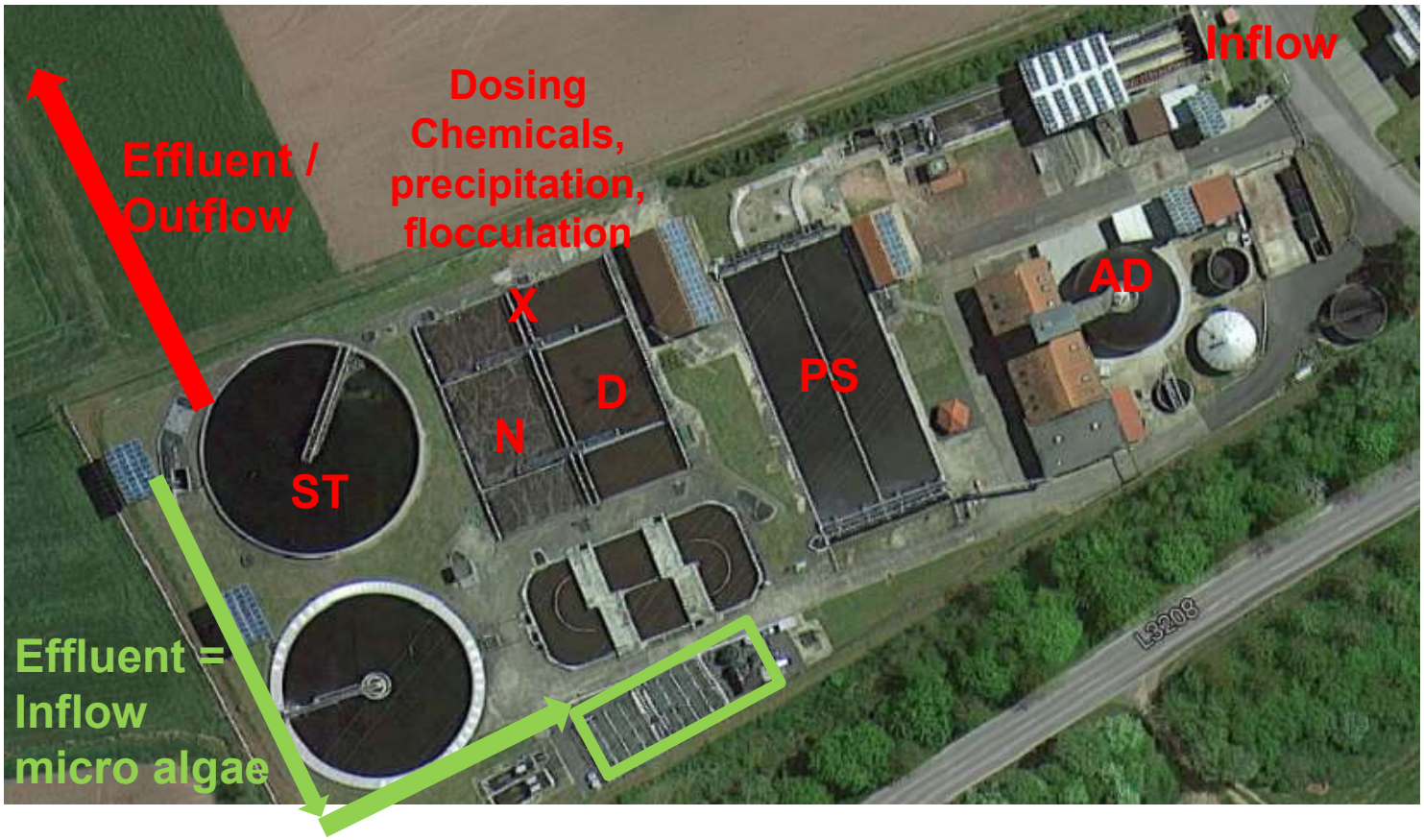
German Wastewater Regulations (AbwV, Anhang 1, 1997, zuletzt geändert am 29.03.2017
new requirements in Hesse acc. Program of Measures in Hesse, acc. EU Water Framework Directive 2015-2021 (HMUKLV, 2015)

Reason of the project 2015-2017 Rotenburg:

- WWTP Rotenburg-Braach: 34.000 PE: class 4
  monitoring value: P_{tot} = 0,7 mg/l (2-h-sample)
  limit value: o-PO_4-P = 0,2 mg/l (24-h-sample)
- Reduction nutrient loads (nitrogen) and organic loads (COD) to preserve the water body (Fulda)

Idea: targeted use of microalgae for nutrient removal

- **Phosphorus removal**, secondary objective: nitrogen and COD removal
- to avoid using chemicals for phosphorous removal (precipitants Fe, Al)
  → reducing operating cost of WWTP
- production of algal biomass for biogas production (energy recovery)
- use of the algal biomass as fertilizer



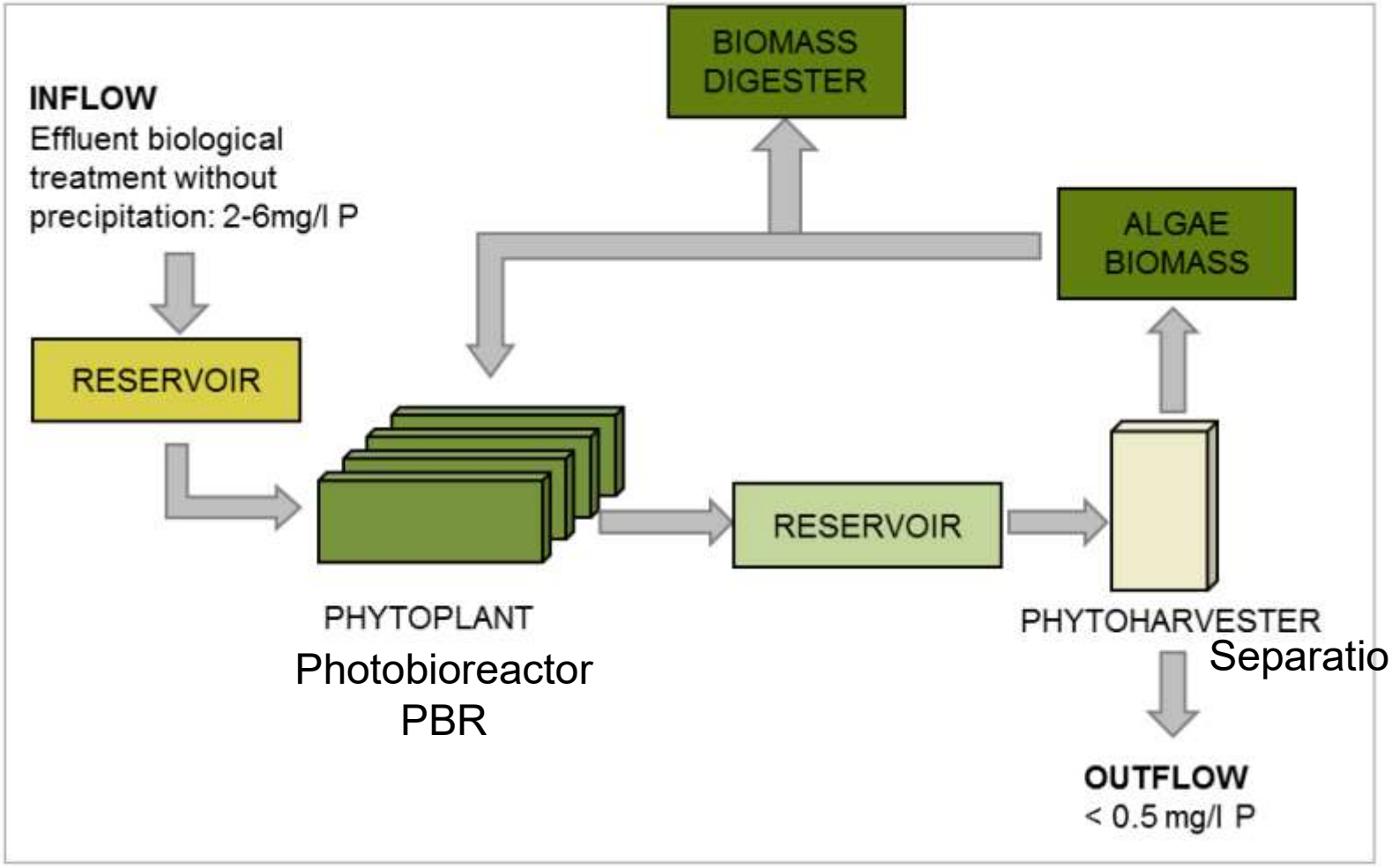
Wastewater treatment plant Rotenburg Braach: 34.000 PE

- Primary Sedimentation
- Activated sludge system
- Nitrification / Denitrification
- Secondary settling tank
- Anaerobic Sludge Digestion

Pilot plant micro algae
Inflow Pilot Plant = Effluent WWTP

https://www.google.de/maps/place/Braach,+36199+Rotenburg+an+der+Fulda/@51.010594,9.6825432,1035m/data=!3m1!1e3!4m5!3m4!1s0x47bb54c1e1bf43a9:0xa224352a7b29370!8m2!3d51.0032567!4d9.6908037

Pilot plant operating scheme

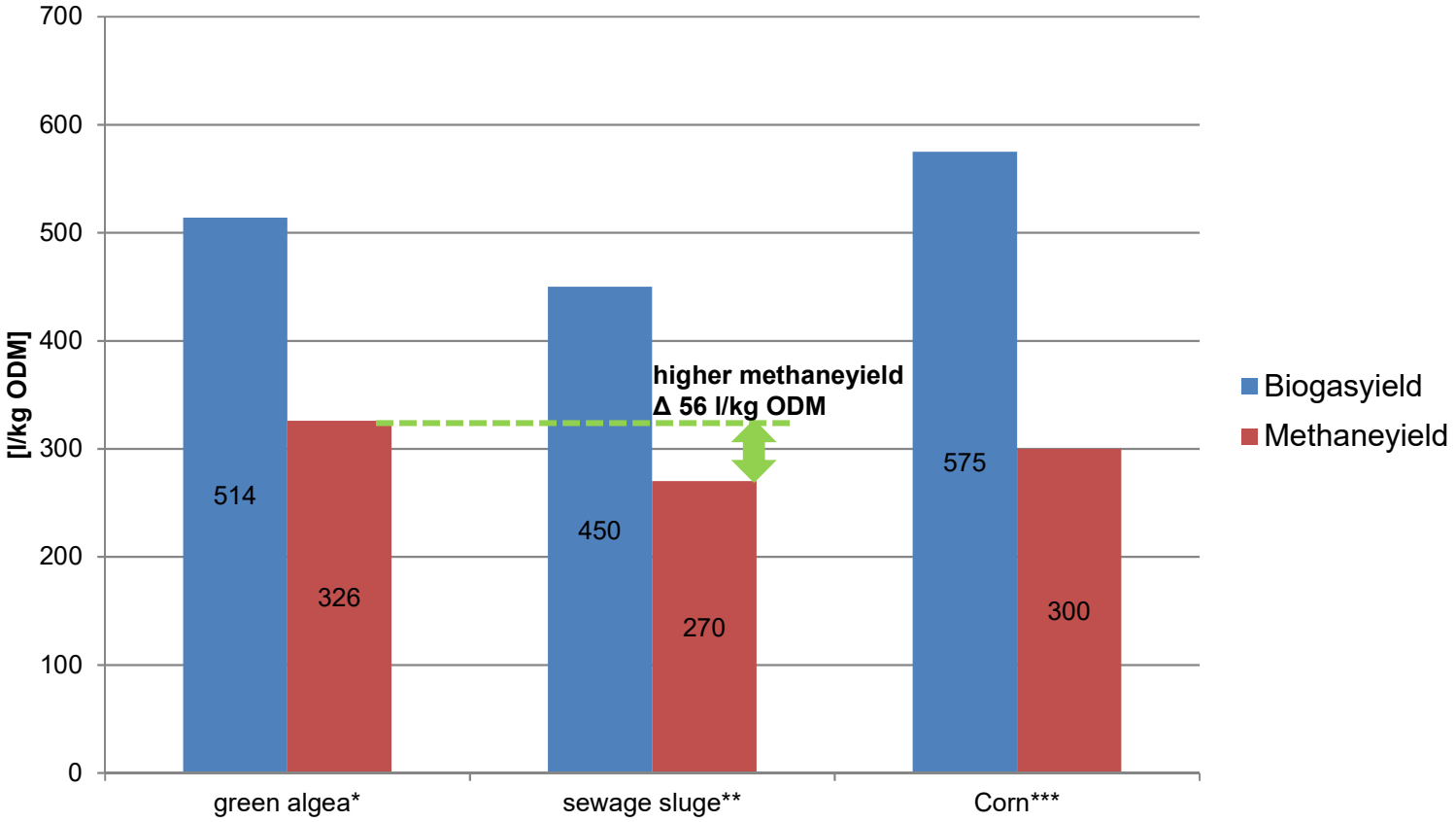


Phytobags

Results of nutrient removal

Para-meter		Outflow WWTP = Inflow PBR	Outflow WWTP with N and P addition	Outflow PBR	Removal rate PBR
NH_4-N	[mg/l]	0,3 - 3,1	< 5	0,02 - 0,50	85 – 98 %
NO_3-N	[mg/l]	1,2 - 5,3	ca. 15 – 44	0,23 - 0,90	82 – 97 %
PO_4-P	**[mg/l]**	**0,4 - 0,6**	**3,0 – 11,0**	**0,04 - 0,68**	**72 – 99 %**
Ptot	**[mg/l]**	**0,5 - 1,1**	**3,8 - 11,5**	**0,05 - 0,88**	**55 – 97 %**

Biogaspotential with green algae cosubstrat



* green algae mixture Chlorella vulgaris & Scenedesmus cosubstrat, inoculum: sewage sluge
** sewage sluge from sewage treatment plant Gießen
*** Corn cosubstrat, inoculum sewage sluge
[biogas potential tests are made by THM Gießen, test are made as duplicate]

Conclusions

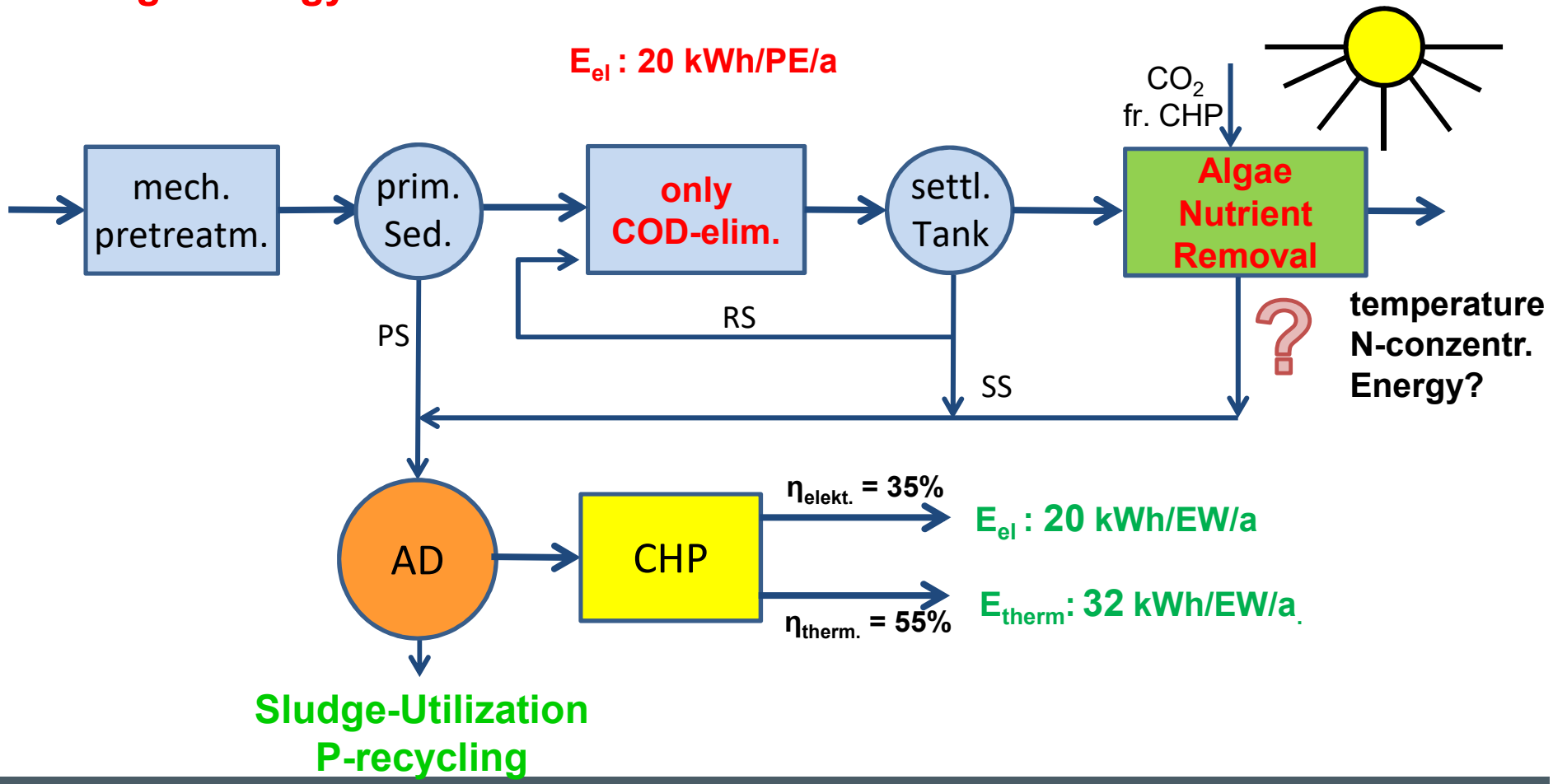
- High nutrient removal rates are possible
  (P_{tot} < 0,5 mg/l, PO_4-P < 0,2 mg/l)
- Potential of reducing operating costs
  (less chemicals or avoiding chemicals (precipitants Fe- or Al-)
- Seperating biomass with phytoharvester (membrane filtration) must be enhanced (too expensive)
- Energy yield from use of the algae biomass for biogas
- **Nutrient removal with microalgea represents an alternative solution for P-elimination with precipitant**

Fields requiring further research:

- Identify further reaction constants and factors that influence the process (kinetic constants)
- Adaption to mathematical models (ASM)
- Dependence of sunlight, temperature and pH-value
- Technology, required volume and area of the PBR (Photobioreactor)
- Optimal use of the algal biomass (biogas, P-ressource, fertilizer, ….)
- **There is still a large scope for the improvement and optimization of the process**

Future strategy to impove nutrient removal and energy consumption

No longer energy-intensive nitrification



Our experiences	What we are looking for
general experience in municipal and industrial wastewater treatment	Experience in kinetics of green algea in wastewater treatment
municipal wastewater sluge treatment and anaerobic process engineering	Experience in nutrient recycling and fertilizer ordinance
creating energy concepts for wastewater treatment plants	Experience in biomass seperation and process design for cultivation
Experiences in wastewater treatment with microalgae under real conditions (research project in pilot scale)	EU Partner
2 PhD studies; Nutrient removal, P-recycling; AlgA project (2018) BMBF	Experience micropollutants removal with algae

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Thank you for your attention

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