European Union

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"Sustainable Manure Management from the Biogas Production and Greenhouse Gases Emissions Perspective"

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GreenAgri 2016, Jelgava, Latvia

Agriculture and biogas production?

Mainly energy production technology?

(maize based German example)

or

By-products stabilization and organic fertilizer production technology that as an additional value reduces GHG emissions and collects these as biogas!!!

For minimal ecological footprint and maximal resource efficiency

Anaerobic digestion

has to be considered as

Waste stabilization and organic fertilizer production technology, with additional value of biogas production!

Back to the basics with agri biogas plants ...

... for dairy farms biogas production is considered as a **fully integrated part of production residues treatment**, not separate **energy production business**

Sustainability and positive environmental impact of manure mangement by anaerobic digestion process

Positive environmental impact of biogas plants

- **Reduction of fossil fuels consumption for production of energy and mineral fertilizers**

  1 dairy cow yearly manure amount allows to produce**: 1095 kWh** electricity and **1229 kWh** heat or **273 l gasoline** equivalent of transport fuel

  Haber- Bosch process consumes **45 MJ = 12,5 kWh energy for production of 1 kg N-NH_3.**

- **Reduction of nutrients loss and run-off during or after digestate land application**

  N in digestate is in higher proportion in readily available form (NH_4-N) for plants- if applied at right time with proper spreading technologies then it is possible to have minimal nutrients loss

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Positive environmental impact of biogas plants

- **Smell nuisance reduction during digestate land application**

During anaerobic digestion most of the organic acids in manure are converted to biogas which significantly reduces the offensive smell of the digestate. If digestate is applied with injection technology, then it is also possible to reduce to minimum ammonia specific smell nuisance

- **GHG emissions reduction**

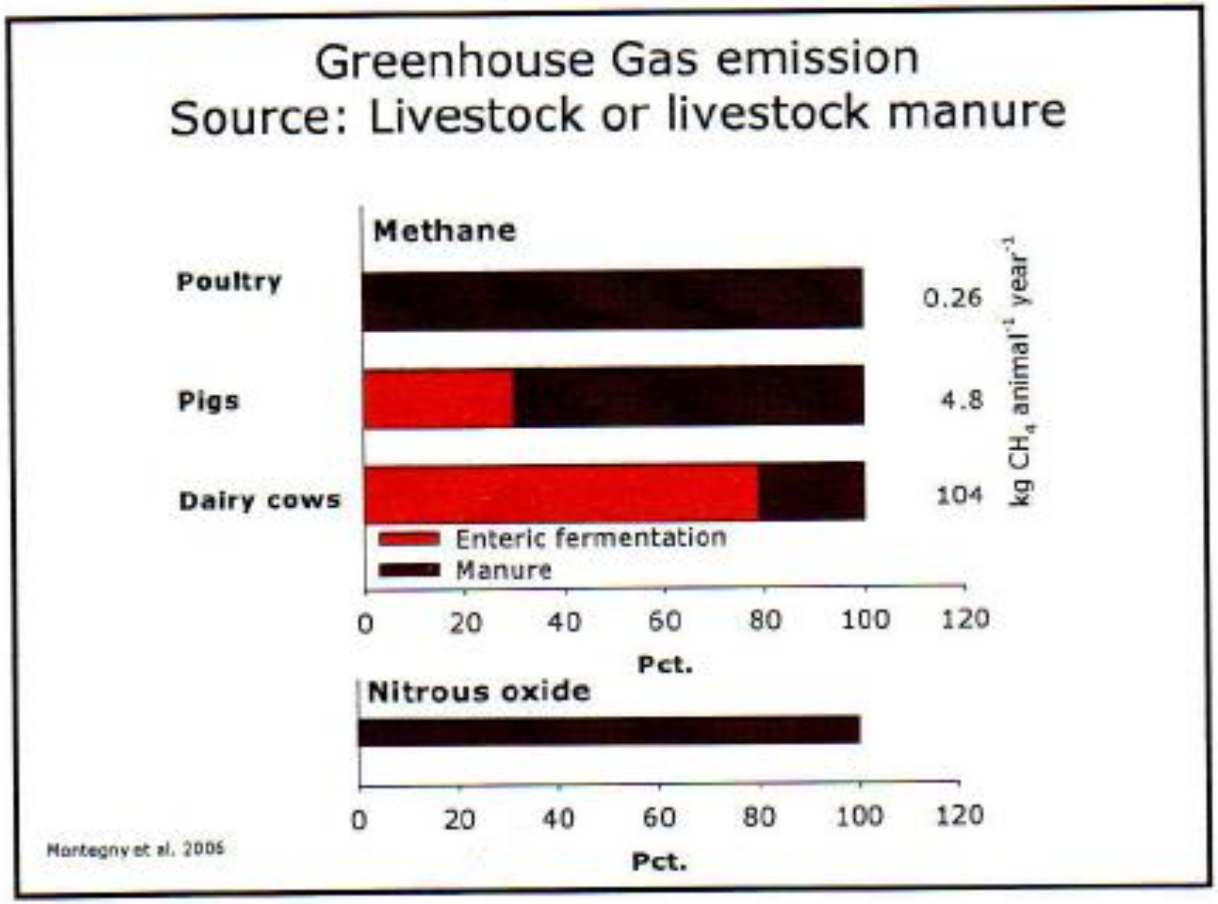
IPCC has declared that agricultural sector is responsible for 37% of all the anthrophogenic CH_4 emissions and 65% of the N_2O emissions

Liquid manure handling and storage is mainly related to CH_4 emissions and **solid manure mainly with N_2O emissions**

CH_4= 21* CO_2 ekv. ; N_2O = 298* CO_2 ekv.

How much can we really influence GHG emissions from manure management viewpoint?

GHG emissions from livestock industry



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GHG emissions reduction

Estonian conditions based calculations

CH_4 emissions from dairy cattle enteric fermentation, kg CH_4/animal/year					
	Dairy cattle	Beef cattle (bull)	Beef cattle (cow)	1-2 year. animals	Below 1 year animals
Estonia	124	59,0	67,7	62,7	34,4

CH_4 emissions from manure, kg CH_4/animal/year					
	Dairy cattle	Beef cattle (bull)	Beef cattle (cow)	1-2 year. animals	Below 1 year animals
Estonia	10	4,04	4,63	4,65	2,23

- Based on IPCC report data of year 2007, then N_20 emissions from cattle industry were 284 t N_20/year (98 % from solid manure) and CH_4 emissions of 1448 t CH_4/year
- **In total cattle industry GHG emissions were = 115 040 t CO_2 equivalent**

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GHG emissions reduction

Estonian conditions based calculations

- If all liquid and solid manure in Estonia would be stabilized in biogas plants then it would be possible to avoid:

2007. a IPCC report	Emissions t/year		Emissioon t CO_2/year
Bovine	1477,8	t CH_4	31 033,8
Sheep	13,8	t CH_4	289,0
Goat	0,5	t CH_4	10,1
Horses	0,7	t CH_4	15,6
Pigs	1231,7	t CH_4	25 865,3
Poultry	115,3	t CH_4	2 420,3
Total solid manure open storage	**277,4**	**t N_2O**	**82 661,7**
Total			**142 295,7**

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From the manure management GHG reduction viewpoint most important is to focus on the solid manure anaerobic digestion and N_2O emissions reduction

Solid manure open storage - biggest source of GHG emissions from livestock industry

Example CO_2 balance in the context of potential revenue from CO_2 trading

1000 head dairy cattle herd liquid manure anaerobic digestion:

- During produced biogas burning emission is **489,5 t CO_2**
- Via manure digestion **210 t CO_2 eq.** Emissions are avoided
- With produced renewable energy **1182,6 t CO_2** emissions are avoided from replacement of oil shale based energy production
- Mineral fertilizer replacement with digestate as organic fertilizer. If compared energy source is natural gas used for Haber- Bosch, then **384, 4 t CO_2** are avoided

Total CO_2 emissions reduction= 489,5 -210 -1182,6 -384,4=

= -1287,5 t CO_2 aastas

Prognosed CO_2 price for 2020 is 20 EUR/t =

25000 EUR/year potential revenue if manure management will be part of trading scheme

For solid manure AD the perspective is even more attractive!

From theoretical calculations to reality

Every MANURE and waste is unique, with its own curiosities and character, so for efficient management you need to know them in detail well in advance!

	TS, %	VS, %	CH4, m³/t	CH4, m³/t VS	
Farm1	14.69	85.05	30.40	246.08	
Farm2	14.34	85.94	29.89	235.95	
Farm3	14.13	84.13	29.22	234.27	
After liquid manure scrapers in storage tank	TS, %	VS, %	CH4, m³/t	CH4, m³/t VS	Water use ratio compared to liquid manure volume
Farm1 pumping station	9.78	77.02	11.41	164.89	50%
Farm2 pumping station	7.69	82.20	12.44	228.24	86%
Farm3 pumping station	6.60	80.85	13.04	170.10	114%

Liquid manure biogas potential variability

Nr	TS%	VS%	m³ CH_4/t	m³ CH_4 / t VS
1	4,77	74,29	9,68	273,17
2	5,30	74,43	11,16	282,78
3	5,32	75,03	11,01	275,75
4	5,32	74,86	12,86	322,79
5	6,45	78,62	11,20	220,84
6	[illegible]	[illegible]	[illegible]	[illegible]
13	8,67	81,83	13,25	186,78
14	8,87	84,67	13,88	184,92
15	10,50	78,60	24,48	296,60
16	10,50	78,60	25,29	306,47
17	11,02	82,51	25,54	280,91
Min	4,77	74,29	9,68	172,93
Max	11,02	84,67	25,54	322,79
Avg	**7,62**	**78,76**	**15,54**	**258,74**
Median	7,84	78,60	13,25	275,75

Manure is not just a manure.

Each of it has its own character!

For solid manure composition and biogas potential most important factor is the bedding material and its use proportion

- Best solution is straw (shredded)
- Peat is not as good, as it is inert organic material
- Minimal storage time guarantees minimal GHG emissions and maximal biogas potential
- Impurities (stones, metal etc)- screws and pumps DEATH

	KA, %	OA, %	CH4, m³/t	CH4, m³/t OA
Young cows (peat)	14.73	82.81	19,75	159,73
Young cows (peat+ straw)	22.87	91.66	44.15	214.77
Young cows (peat)	16.14	84.67	16.56	120.42
Heifers (peat+ straw)	21.41	87.48	22.99	120.40
Solid manure (straw)	15.28	75.89	18.64	160.70

Liquid manure IPCC biogas potential comparison to AD potential

Liquid manure	m^3 CH_4/year	
Enteric fermentation	9.5	IPCC values
Manure storage ambient conditions	0.8	IPCC values
Manure AD	12-15	Avg liquid manure AD

From the above values it is obvious, that AD is the best possible solution for the manure management- avoidance of open storage emissions and beneficial use of the whole energetic potential of the manure!

At the same time AD is also compensating enteric fermentation negative emissions!

Manure management and AD conclusion

- For liquid and solid manure management environmental footprint reduction **anaerobic digestion is the only sustainable solution!**

- **Manure based biogas plants with HRT longer than 10 days are in any design with positive environmental impact** (regarding GHG emissions)

What about digestate?

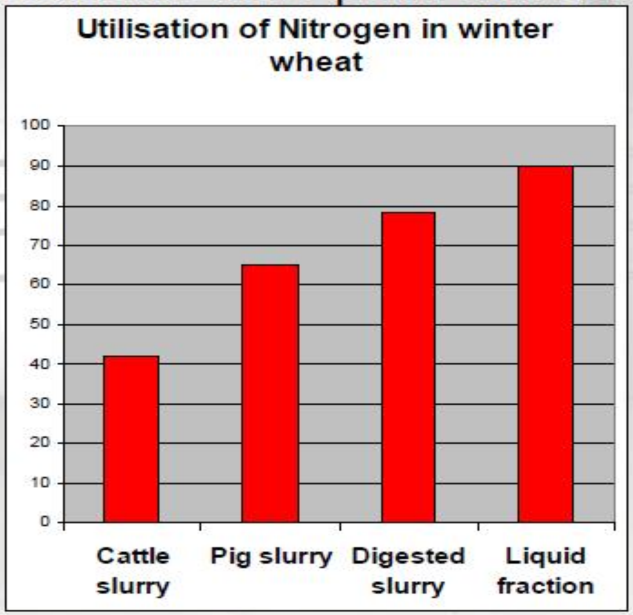
Digestate is a reflection of the substrates composition and quality!

Digestate positive features compared to manure

- Higher ammonia proportion of N
- Reduced smell potential
- Lower viscosity and better flowability
- Allows precision fertilizing

Digestate: advantages

1. Nutrients more plant available

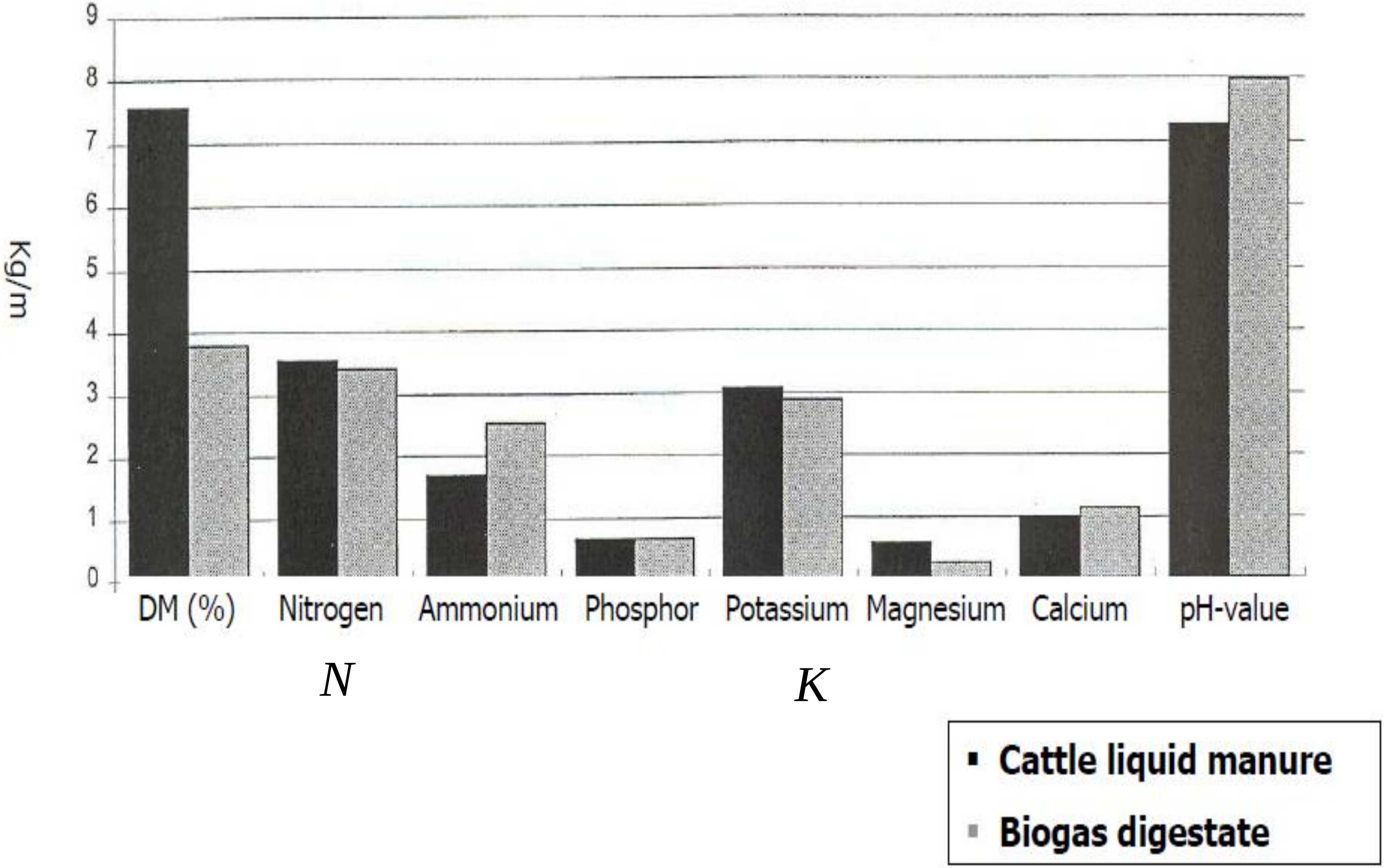


→ Improved N utilisation
Reduced risk of leaching

Directly related to climatic conditions and spreading technology!

(Nielsen, 2006)

Manure vs digestate



Liquid manure and manure (liquid + solid manure) based digestate compositions

	Sample	pH	TS, %	VS, % TS	NH_4-N kg/t	N kg/t	**NH_4-N/$N_{üld}$ %**	P kg/t	K kg/t	Mg kg/t	Ca kg/t
1	Digestate 08.04.2015	7.64	5.41	70.07	2.56	3.85	**0.66**	0.72	2.75	1.01	1.24
2	Digestate 08.06.2015	7.8	6.26	63.18	2.54	3.87	**0.66**	0.71	3.16	0.55	1.29
1	Liquid manure 08.04.2015	7.12	8.72	83.03	1.94	4.1	**0.47**	0.89	2.48	1.11	1.45
2	Liquid manure 08.06.2015	6.95	8.74	70.31	1.85	3.87	**0.48**	0.78	2.64	0.84	1.44

			% of TS			VFA-s, mg/l					
	Sample	VFA/ALK	**Hemi-cellulose, %**	Cellulose, %	Lignin, %	Acetic	Propionic	Iso-butyric	Butyric	Iso-valeric	Valeric
1	Digestate 08.04.2015	0.17	**0.19**	17.07	19.73	36	5.1	3.0	2.1	1.4	2.0
2	Digestate 08.06.2015	0.35	**0.71**	9.24	18.73	181	103	10	1.8	3.6	2.7
1	Liquid manure 08.04.2015	5.22	**16.43**	23.99	14.63	5836	1790	109	511	109.5	57.0
2	Liquid manure 08.06.2015	1.29	**9.88**	22.41	11.91	7994	2229	186	1286	260.3	177.3

Digestate spreading technology

Digestate post-treatment

If there is no land scarcity then best digestate treatment is covered storage and direct land application. With post treatment no additional value is generated, but only additional costs!

Less restrictive legislative framework required to support agri-wastes recycling

Why so bold statement about **AD BEST THING for manure and biodegradable waste management**?

Because AD is biological process based on activity of anaerobic microbial consortia. What is toxic for nature is also toxic for microbial consortia of AD and no one operating biogas plant wants to use as feedstock material that would be toxic for their „small workers“.

What is the problem with manure based biogas production?

As an investment it does not pay off!

(especially in small-scale)

For establishment of manure based biogas plants cost based subsidies required by governments!

or

for feasibility of the plants co-substrates mainly as industrial wastes and energy crops have to be involved in the substrate mix

Mainly used co-substrates are grass or maize silage

Grass silage	TS%	VS%	m3 CH4 / t	m3 CH4 / t VS
1	17.12	96.01	9.94	60.49
2	17.18	91.05	15.26	97.55
3	25.58	91.23	105.56	452.35
4	26.59	92.22	79.93	325.96
5	26.99	89.09	70.45	293.03
6	30.25	91.91	66.45	238.96
7	31.21	88.46	80.09	290.12
8	31.66	91.51	73.96	255.29
9	32.53	92.94	73.38	242.69
10	33.69	89.37	81.85	271.85
11	39.31	91.36	94.59	263.38
12	42.76	90.22	55.99	145.14
13	43.34	91.93	162.42	407.65
14	43.38	92.15	100.93	252.47
15	50.41	88.76	134.45	300.50
Min	17.12	88.46	**9.94**	60.49
Max	50.41	96.01	**162.42**	452.35
AVG	**32.80**	**91.21**	**80.35**	**259.83**
MED	**31.66**	**91.36**	**79.93**	**263.38**
SDV	**9.64**	**1.92**	**38.82**	**102.52**
SDV,%	**29.38%**	**2.10%**	**48.31%**	**39.46%**

For efficient degradation sufficient pre-treatment and appropriate digestion process design required

Otherwise

Problem with last picture?

- Co-substrates pre-treatment is not sufficient
- AD process design is not appropriate- too short HRT

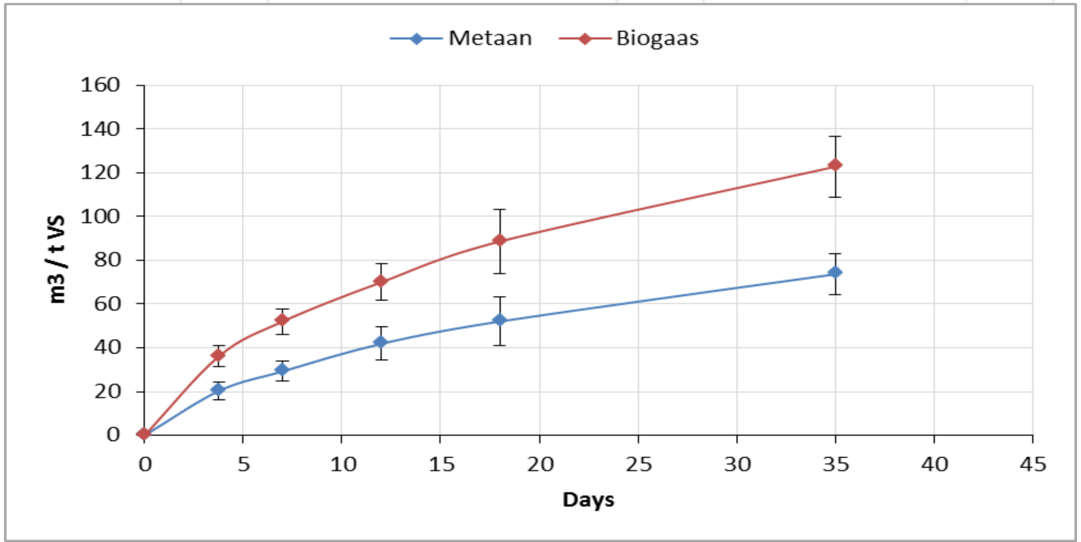
But this is topic of another longer lecture!

- Decreased conversion efficiency (increased digestate residual biomethane potential- values up to 30% of the input potential)- **significant economic loss!**
- From GHG emission point of view such biogas plants could even be with **negative environmental impact!**

How to assess the real situation with digestate residual biogas potential?

- In TUT we have established analytical monitoring tools and complex package for whole biogas plant residual biogas potential measurement

Sample	TS%	VS%	m3 CH4/t	m3 CH4/t VS
Fermenter 1	8.05	77.65	5.6	89.8
Fermenter 2	8.27	78.29	5.8	90.4
Post -Fermenter	6.75	75.70	2.5	48.4



Proposal for cross-border collaboration project

Estonian and Latvian biogas sector detailed investigation from process efficiency and residual biomethane potential monitoring viewpoint

Objective of the project:

Biogas sectors increased profitability with positive environmental impact!

If You are interested in biogas production, or need process analysis or optimization related services then ...

We are in TUT in the process of establishing **Estonian Biogas Competence Centre**

Our mission is to provide **laboratory support for Estonian and Latvian biogas sector develpoment and process efficiency increase** in terms of the complete biogas production process cycle- **from resource analysis to running process optimization**

For today we have established analytical and experimental basis that allows us to carry out all the necessary analysis for biogas production resources, process optimization and research experiments

Thank you for your attention!

Questions?

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