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Fugitive methane emissions from biogas facilities

Based on IEA Report: Methane Emissions from biogas plants

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Agenda

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Emission sources

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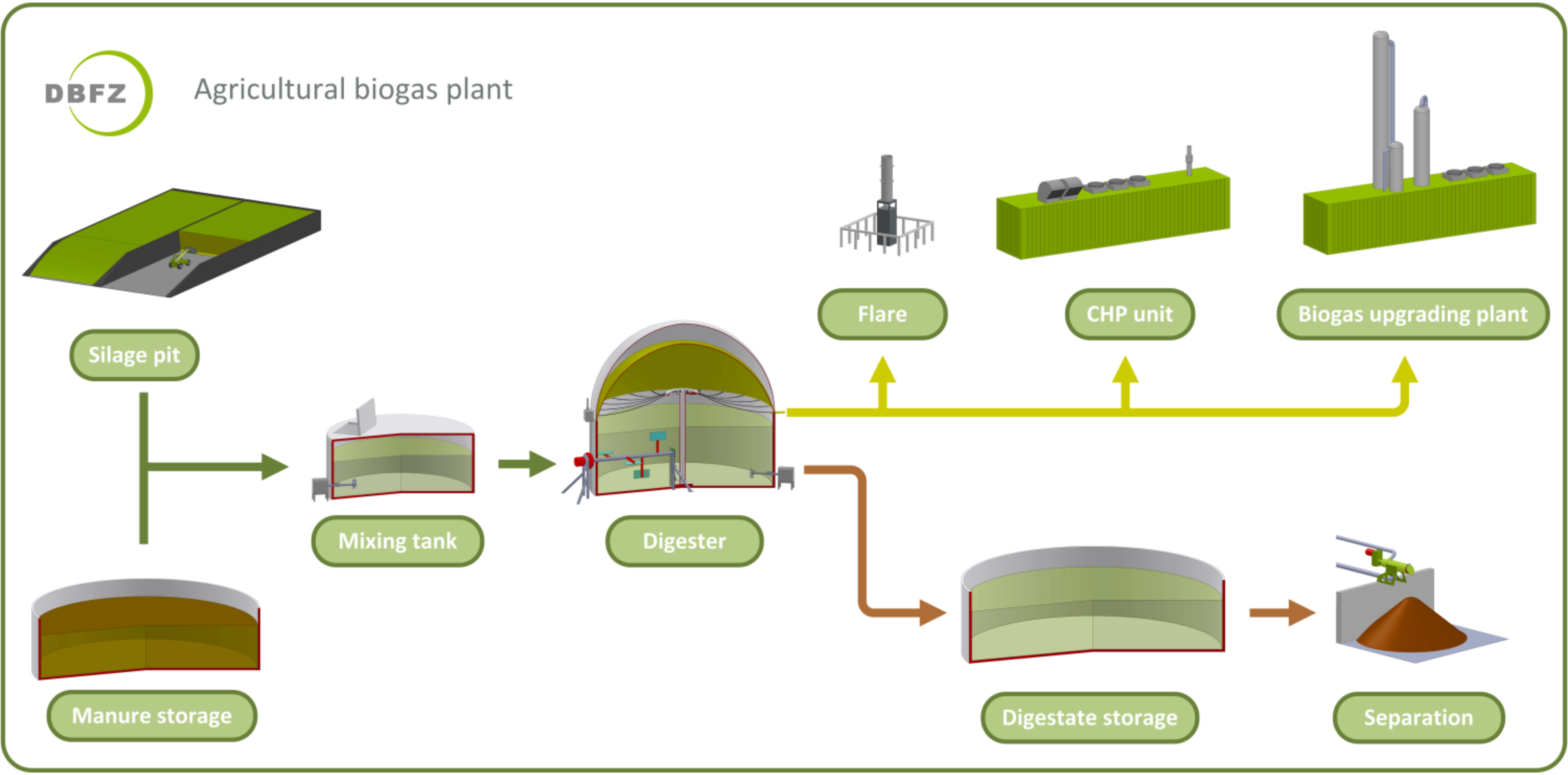

Emissions can be caused by construction or operation

Measurement of emissions - challenges

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Sources:

Point and area sources, known and unknown, constant and time variant

Methods:

Two major strategies (on site (single source) and off site (remote sensing))

Different (sub)methods

No standards for the methods, no clear distinction between different approaches

Documentation of methods, interpretation of results unclear

Technology

New technology, e.g. rubber domes are changing and longtime experience and technical standards are missing or under development

Highly individualized plants

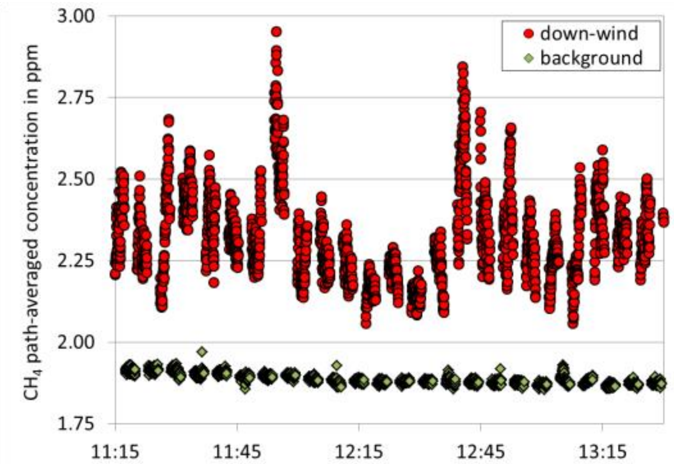
Gas cameras available

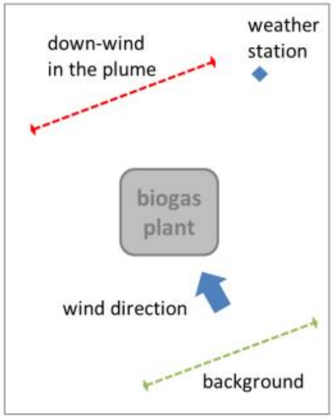
Driver for reduction

Safety related regulation (methane emissions from biogas facilities are rarely regulated yet), acceptance, certification, economics, GHG reduction

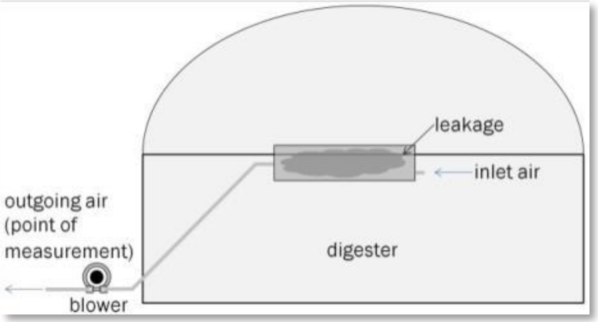
Measurement methods

Remote sensing





On site, single source measurement



All pictures: DBFZ

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Source specific results

Some results and trends - Leakage identification

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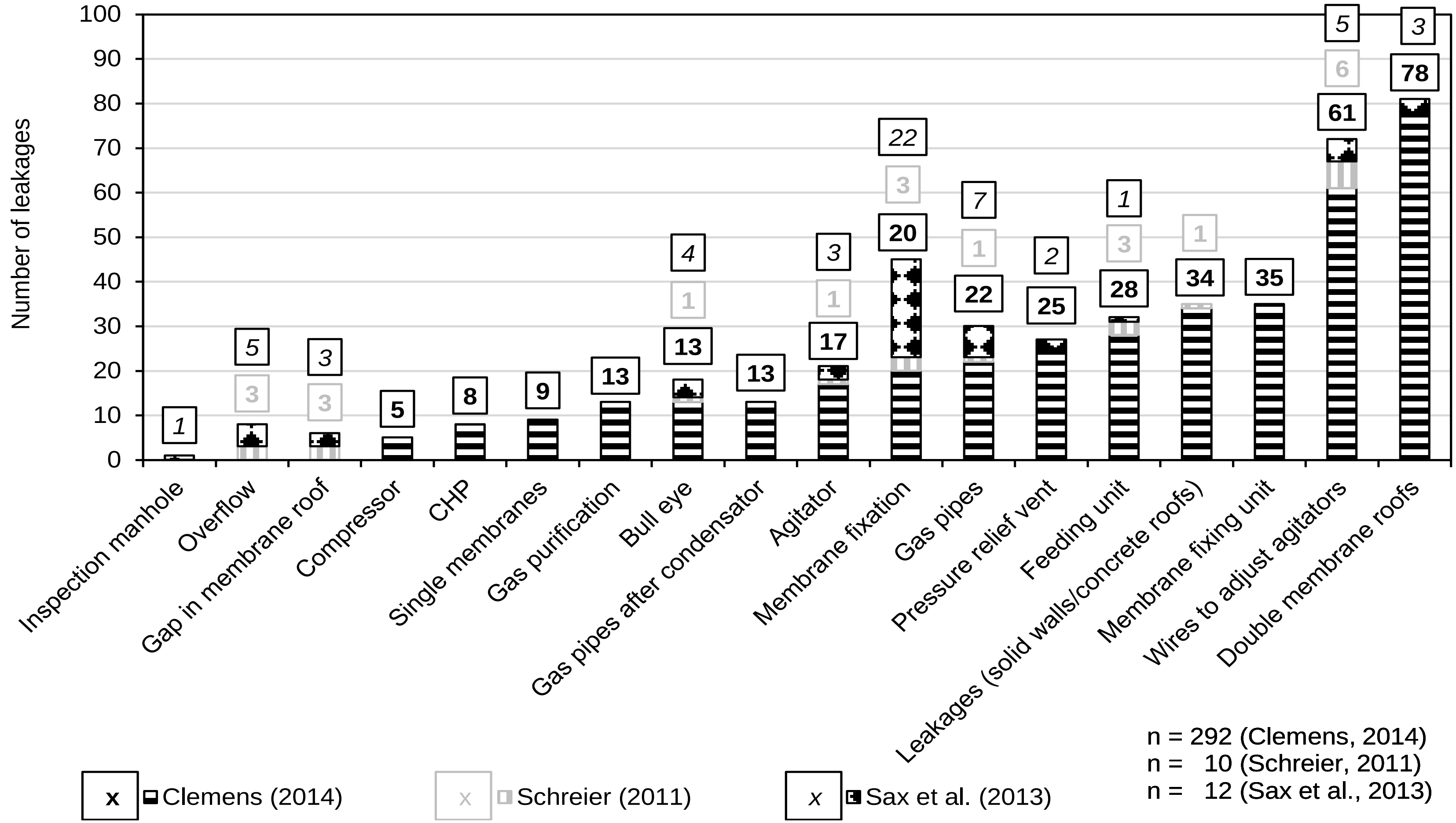

- Almost every site shows leakages of varying emission rates
- Transfer of measured leak emissions (or any “no standard operation) to longer periods of time (e.g. for LCA or certification) is difficult

Double layer air inflated membrane roofs

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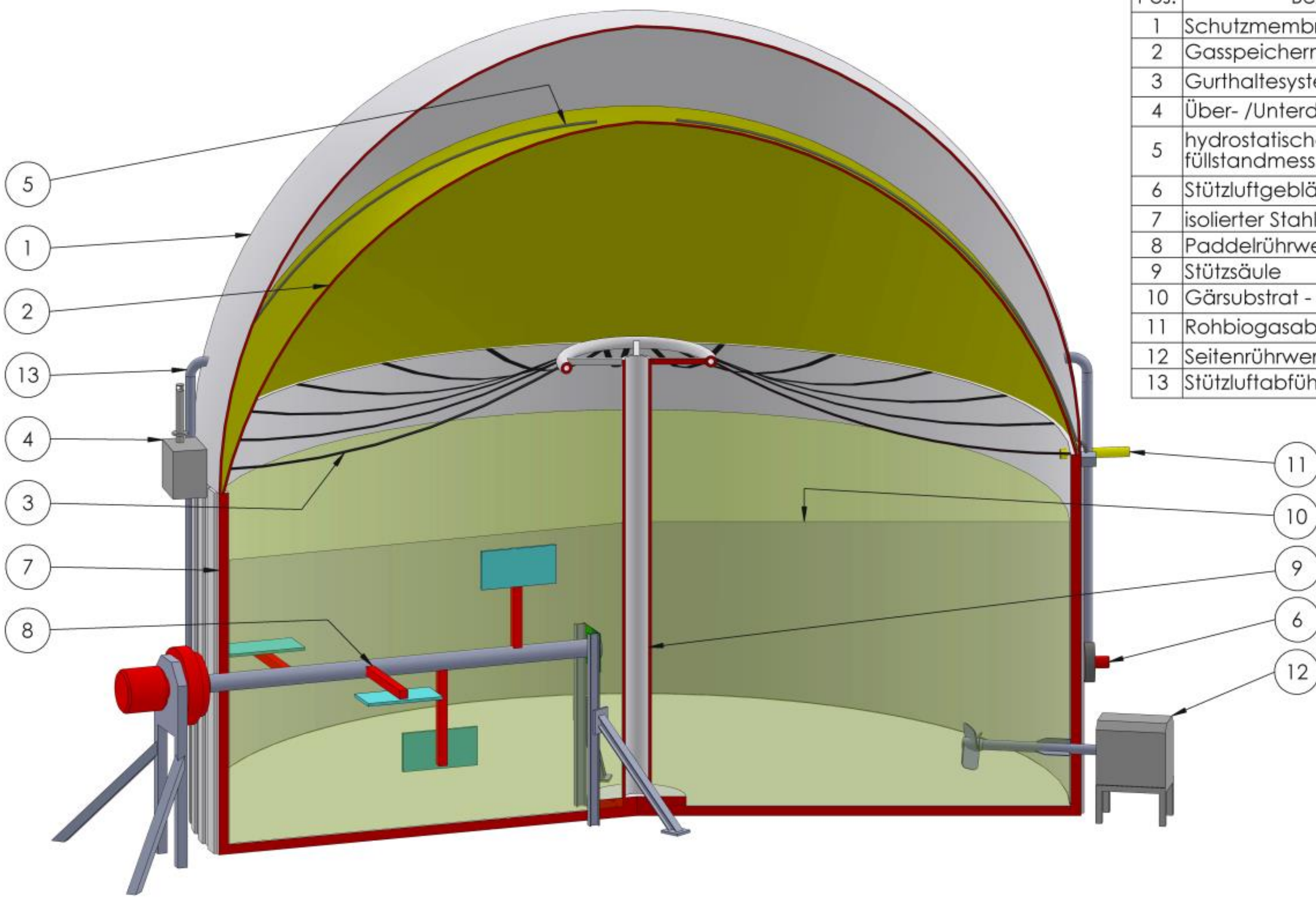

Pos.	Bezeichnung
1	Schutzmembran
2	Gasspeichermembran
3	Gurthaltesystem
4	Über- /Unterdrucksicherung
5	hydrostatisches Gasspeicher-füllstandmesssystem
6	Stützluftgebläse mit Stauklappe
7	isolierter Stahlblechmantel
8	Paddelrührwerk
9	Stützsäule
10	Gärsubstrat - Freispiegel
11	Rohbiogasableitung
12	Seitenrührwerk
13	Stützluftabführung mit Stauklappe

Emission sources: Diffusion, leakage and pressure relief events

Double membrane roofs, methane emissions from the support air (air inflated roof)

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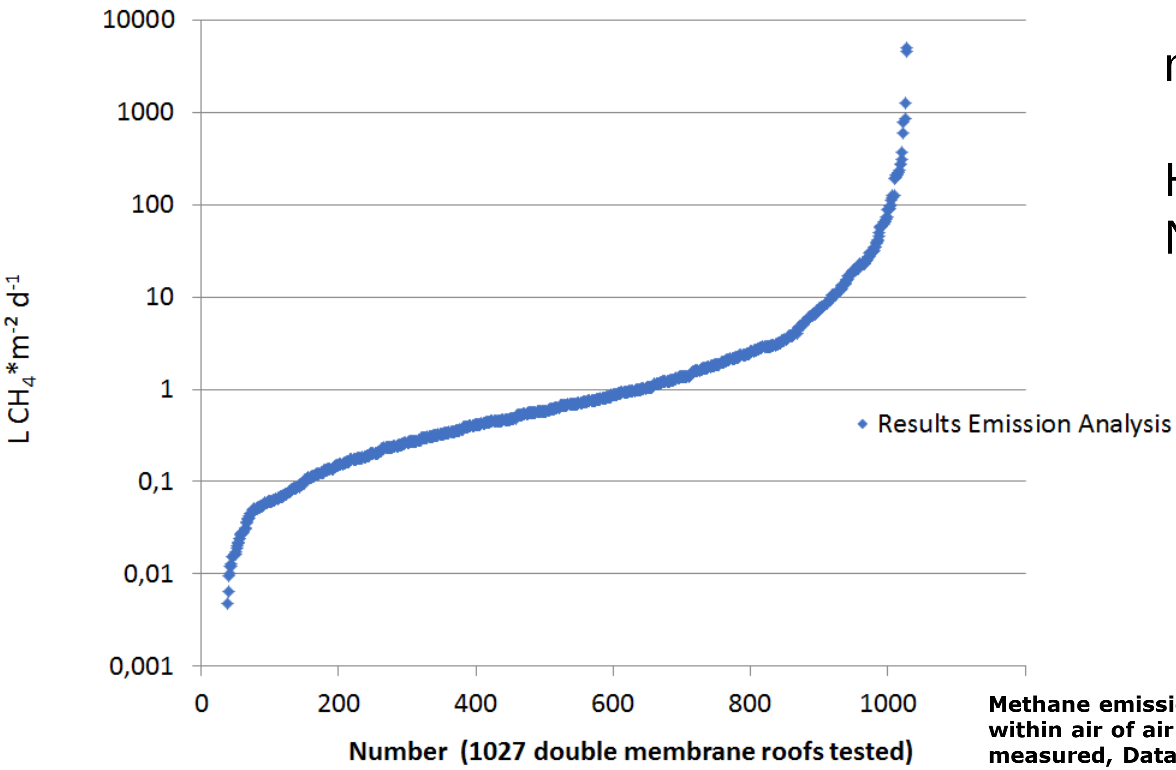

Threshold for diffusion of membranes in Germany:

Hitherto: 1 l CH_4/(m² bar d)
New: 0,5 l CH_4/(m² bar d)

Methane emission through membrane covers based on measurement within air of air inflated double membrane roofs (1027 roofs measured, Data from Clemens et al.)

- Diffusion and leakage difficult to distinguish
- Frequent quality control at membrane roofs is necessary
- Method development and definition of gas tight and when measures have to be taken

Weather and overpressure release events

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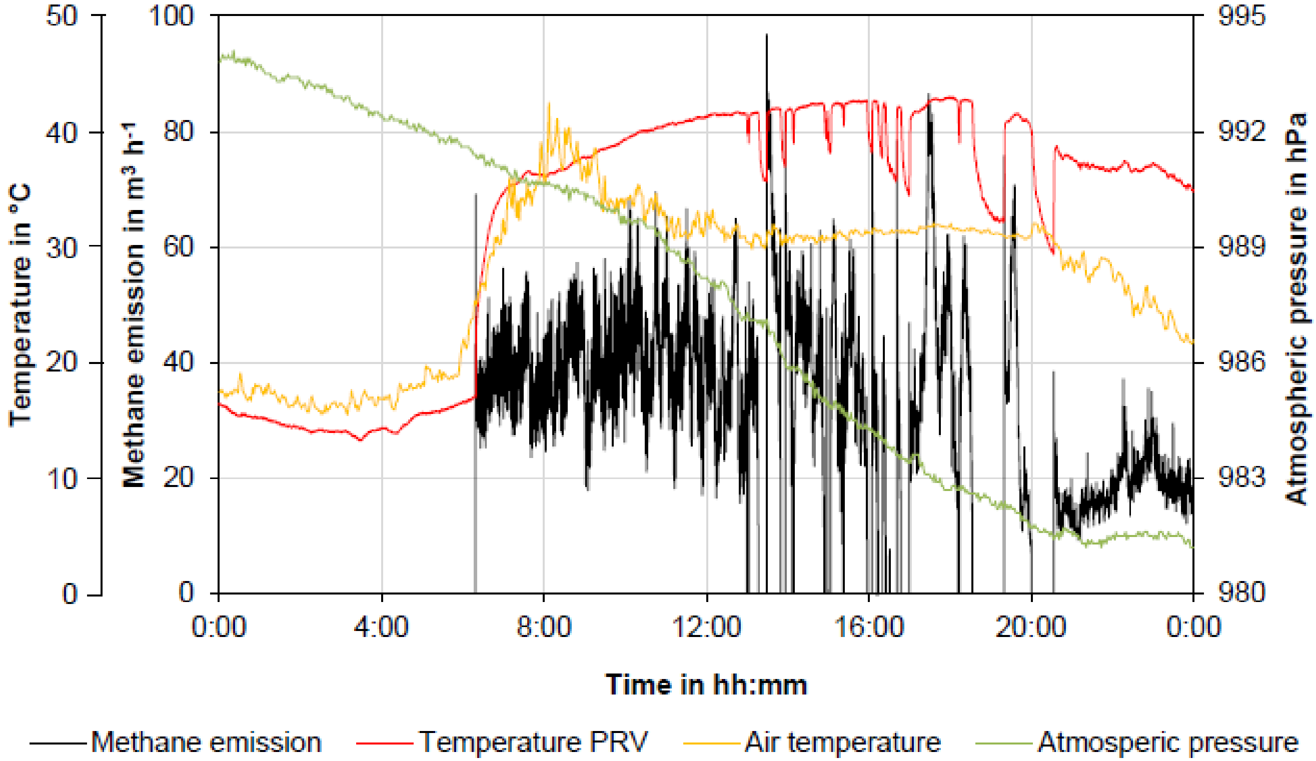

Atmospheric conditions may result in pressure relief events

30 K temperature change results in 20 % volume increase (gas extension and water vapour)

Source: Reinelt, T.; Liebetrau, J.; Nelles, M. (2016): Analysis of operational methane emissions from pressure relief valves from biogas storages of biogas plants. Bioresource Technology; 217, pp. 257–264.; Doi:10.1016/j.biortech.2016.02.073.

Digestate storage

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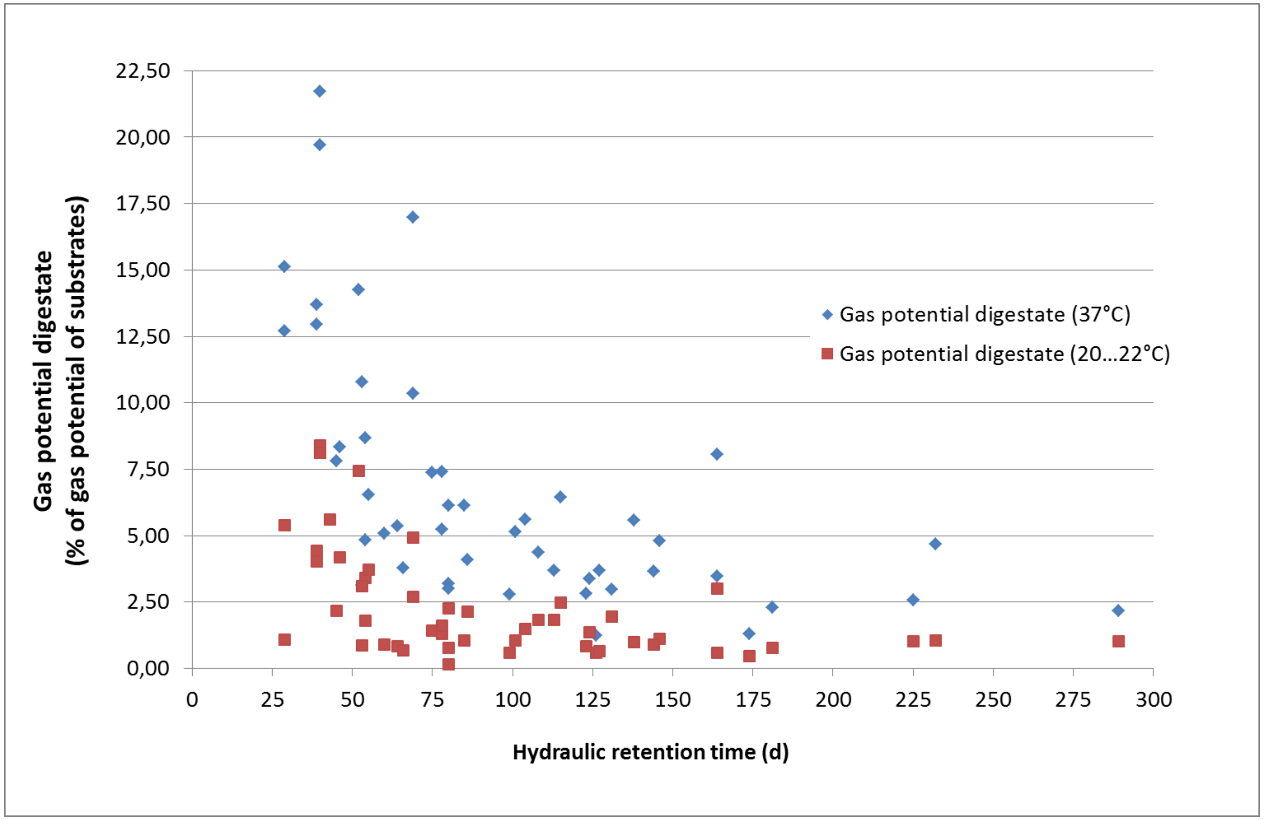

Difficult to analyse with single measurement due to changing temperature and filling level

Model based on remaining gas potential, filling level and temperature most precise option

Data from: FNR – FACHAGENTUR FÜR NACHWACHSENDE ROHSTOFFE E.V. (2010). Biogas-Messprogramm II - 61 Biogasanlagen im Vergleich, 1st ed. Fachagentur Nachwachsende Rohstoffe e.V., Gülzow. Available at: https://mediathek.fnr. de/biogas-messprogramm-ii-61-biogasanlagen-im-vergleich. html (last access: 5th January 2017).

Biogas and natural gas CHP

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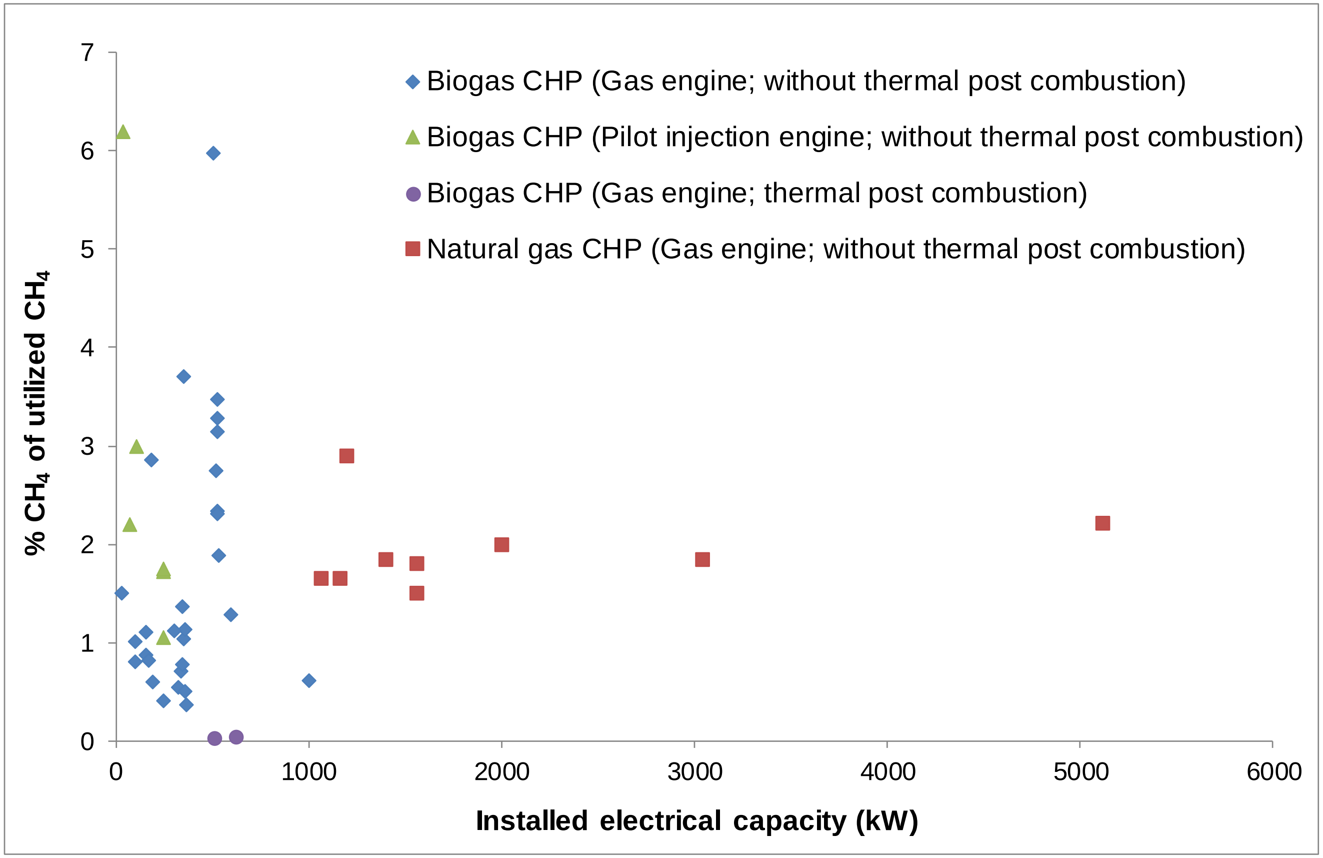

Methane emissions from CHP units operated with biogas and natural gas (Liebetrau, 2013a; Aschmann, 2014, Kretschmann, 2012; van Dijk, 2012)

CHP emissions dependent on engine type, settings, maintenance.
Post treatment can reduce emissions next to nothing (no catalyst available, post combustion systems necessary)

Overall plant emission rates

Emission measurements – Overall plant results

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Approach	Plant type (Number of investigated plants)	Measured methane emission rate	Literature
On-site method (leakage detection, standard methods, dynamic and static chambers)	Agricultural biogas plants (8) Biogas plants with upgrading unit (2)	2 – 25 g CH_4 kWh_{el}^{-1}	Liebetrau et al. (2013)
	Biowaste treatment plants (10)	15 – 295 kg CO_{2eq} Mg^{-1}_{Waste}	Daniel-Gromke et al. (2015)
On-site method (permanent monitoring of pressure relief valves)	Agricultural biogas plants (2)	Plant A 0.1 % CH_4 Plant B 3.9 % CH_4	Reinelt et al. (2016)
Remote sensing approach (IDMM)	Agricultural biogas plants (5)	1.6 – 5.5 % CH_4	Hrad et al. (2015)
	Agricultural biogas plant (1)	3,1 % CH_4	Flesch et al. (2011)
	Agricultural biogas plant (1)	4 % CH_4	Groth et al. (2015)
Remote sensing approach (TDM)	Waste water treatment plant (1)	2.1 – 32.7 % CH_4	Yoshida et al. (2014)
On-site method (leakage detection, standard methods, dynamic and static chambers, High volume sampling) Remote sensing approach (IDMM and TDM)	Biowaste treatment plant (1)	0.6 – 2.1 % CH_4 0.6 – 3.0 % CH_4	Holmgren et al. (2015)

IDMM…Inverse Dispersion Modeling Method; TDM…Tracer Dispersion Method

Emission measurements – Overall plant results

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- Significant variability of emissions from plants
- Some plants: high variability in time (digestate storage, PRV, operation, leakages)
- Variability in methods – under investigation
- Results often difficult to compare (different methods applied and plant characteristics)
- Difficult to transfer point measurements to extended periods of time
- Difficult to generalize results from single plants to the sector

Greenhouse gas balance

Greenhouse gas balance

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Aim: show significance of methane emissions within GHG balance

Method based on the theoretical and simplified pathways modelled by the Joint Research Centre (JRC) of the European Commission for the default values calculation, Input values as presented in Giuntoli et al. 2015

Substrates (Energy crops, waste, manure); **Methane emissions (0-7%); Heat utilization (0-40%) and parasitic electricity consumption (5-15%)** was investigated

Fossile fuel comparator **(FFC) for electricity** equals 186 g CO2eq./MJ_{el} (669,6 gCO_2/kWh)

Bioenergy installations, a 70 % emission reduction in comparison to the FFC has been assumed (as discussed currently).

The results are plotted together with the **30 % of the FFC**, which corresponds to 55.8 gCO_2/MJ (200,88 gCO_2/KWh).

Greenhouse gas balance

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	MAIZE	MANURE	BIOWASTE
Cultivation	Yield=40.76 t FM/ha Diesel=104.32 l/ha $N_{applied}$=63.24 kg/ha Moisture= 65% $K_{applied}$=38.52 kg K_2O/ha	n.a. moisture=90% credits for avoided raw manure storage=17.5% of methane produced, equals 14.6 % of the methane potential of the manure	n.a. moisture=76.3%
Ensiling	Losses=10% DM Diesel=0.56 l /t_{maize}	n.a.	
Transport	20 km	5 km	20 km
Digestion	VS content=33.6% VS reduction=72% yield=345 l CH_4/kg VS	VS content=7% FM VS reduction= 43% Yield=200 l CH_4/kg VS	VS content 21.7% Yield=438 l CH_4/kg VS

Source: JRC solid and gaseous pathways

GHG balance compared to 30 % FFC

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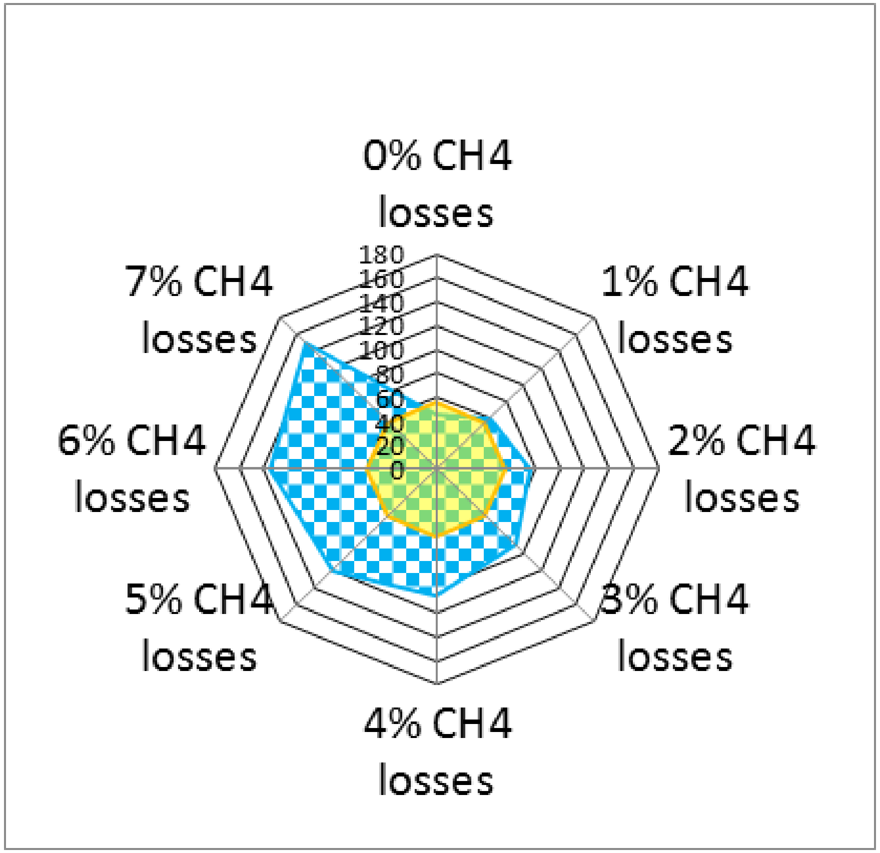

100% maize silage

0% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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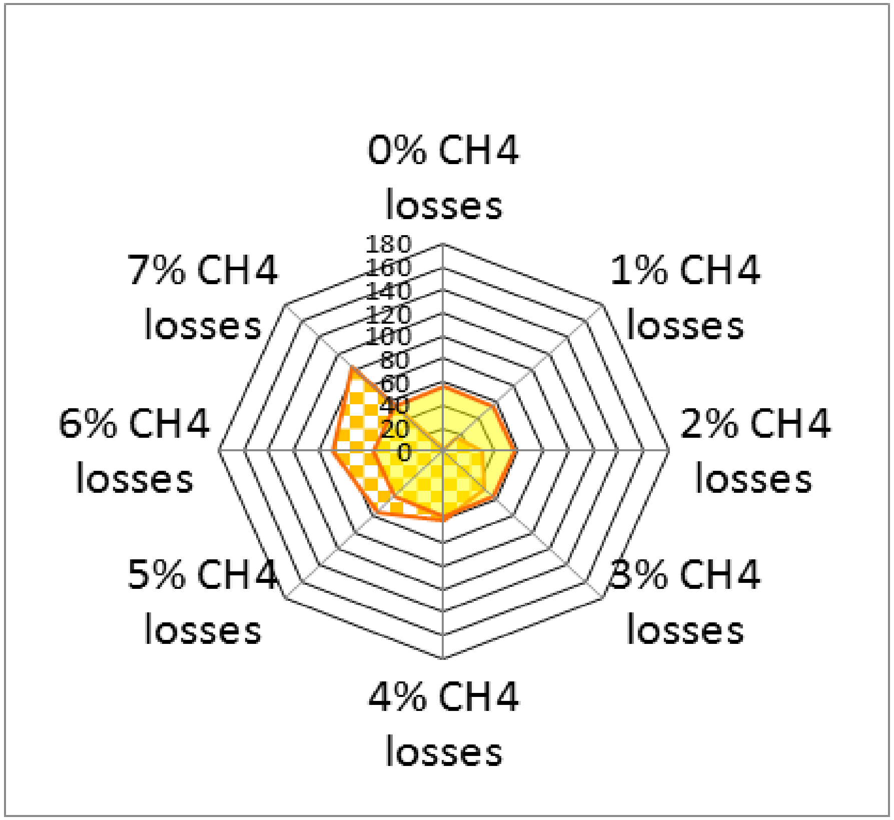

100% organic waste

0% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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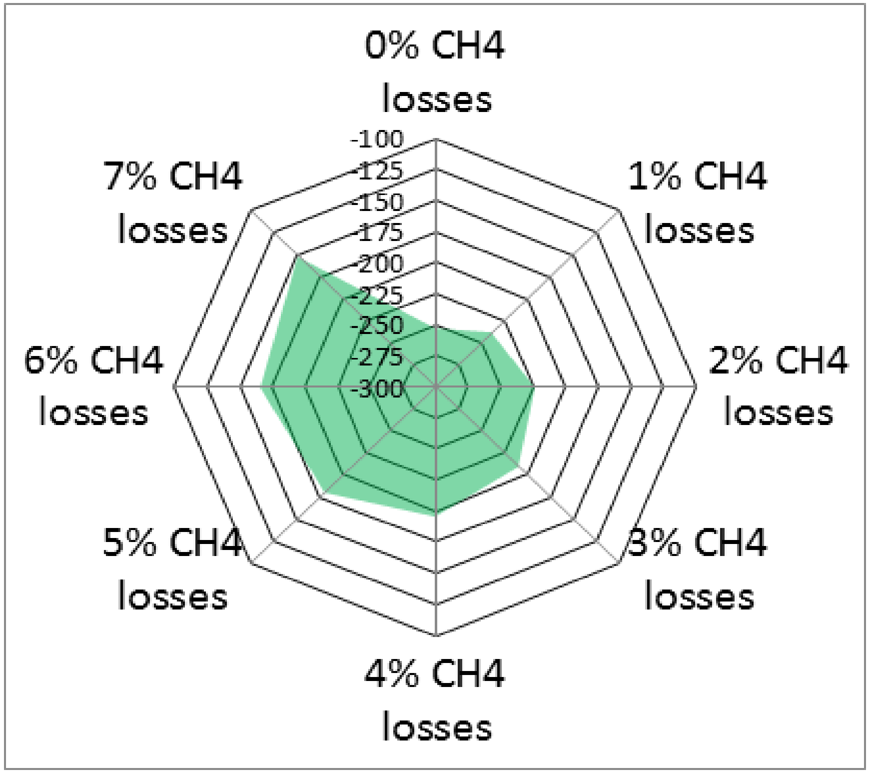

100% Manure

0% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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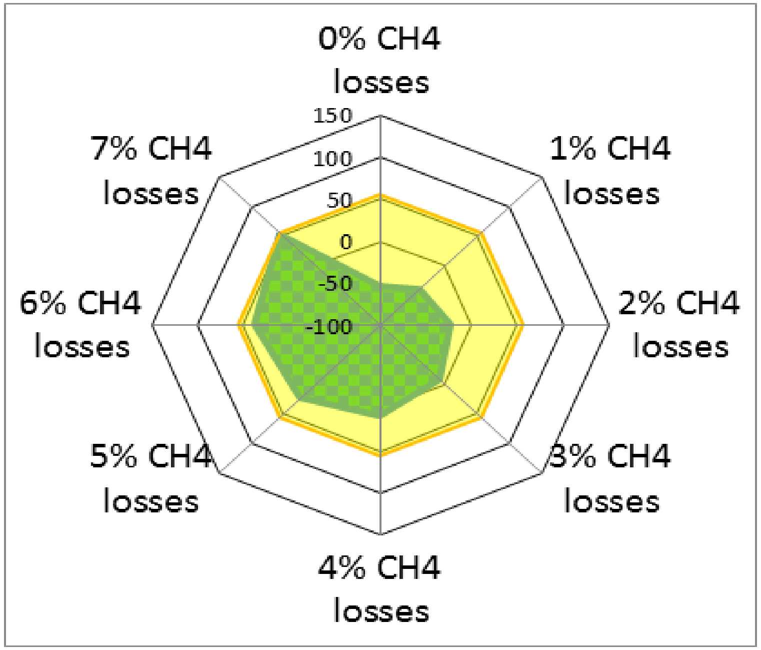
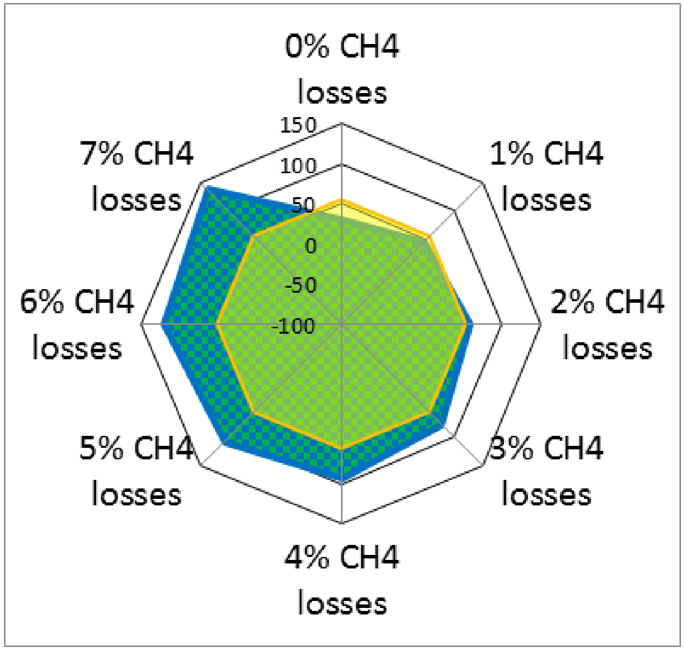


80% Manure/20% Maize Silage

0% Heat utilization

10% electrical parasitc consumption



30% Manure/70% Maize Silage

0% Heat utilization

10% electrical parasitc consumption

Greenhouse gas balance

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- Methane emissions and substrates used are crucial factors for the greenhouse gas balance of AD systems
- Heat utilization can play a significant role in limit cases
- Parasitic electricity consumption is of minor effect
- Energy crop based plants need heat utilization to achieve reduction target of 30 % FFC (assuming CHP emissions as given)
- Co digestion of manure improves balances if a large portion (mass based) of manure is used

Mitigation strategies and conclusion

Conclusions

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- More and more results on single plant evaluations, however limited knowledge about the general situation (different methods and individualized plants)
- Results show variability of emission factors – proper management and technology lead to low emissions
- Method harmonization necessary
- Plants need to be evaluated frequently in order to identify unwanted sources

Mitigation measures:

- Avoid or reduce emissions from digestate storage (and open handling)
- Ensure proper CHP settings and maintenance (Option: post treatment)
- Gas management (flare operation and gas exchange within different storages) and leakage detection
- Substrate change – manure and waste materials improve GHG balance

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Thank you for your attention

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