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Methods for measurement, results and effect on greenhouse gas balance of electricity produced

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Edited by Jerry Murphy

Review by Arthur Wellinger

Emission sources

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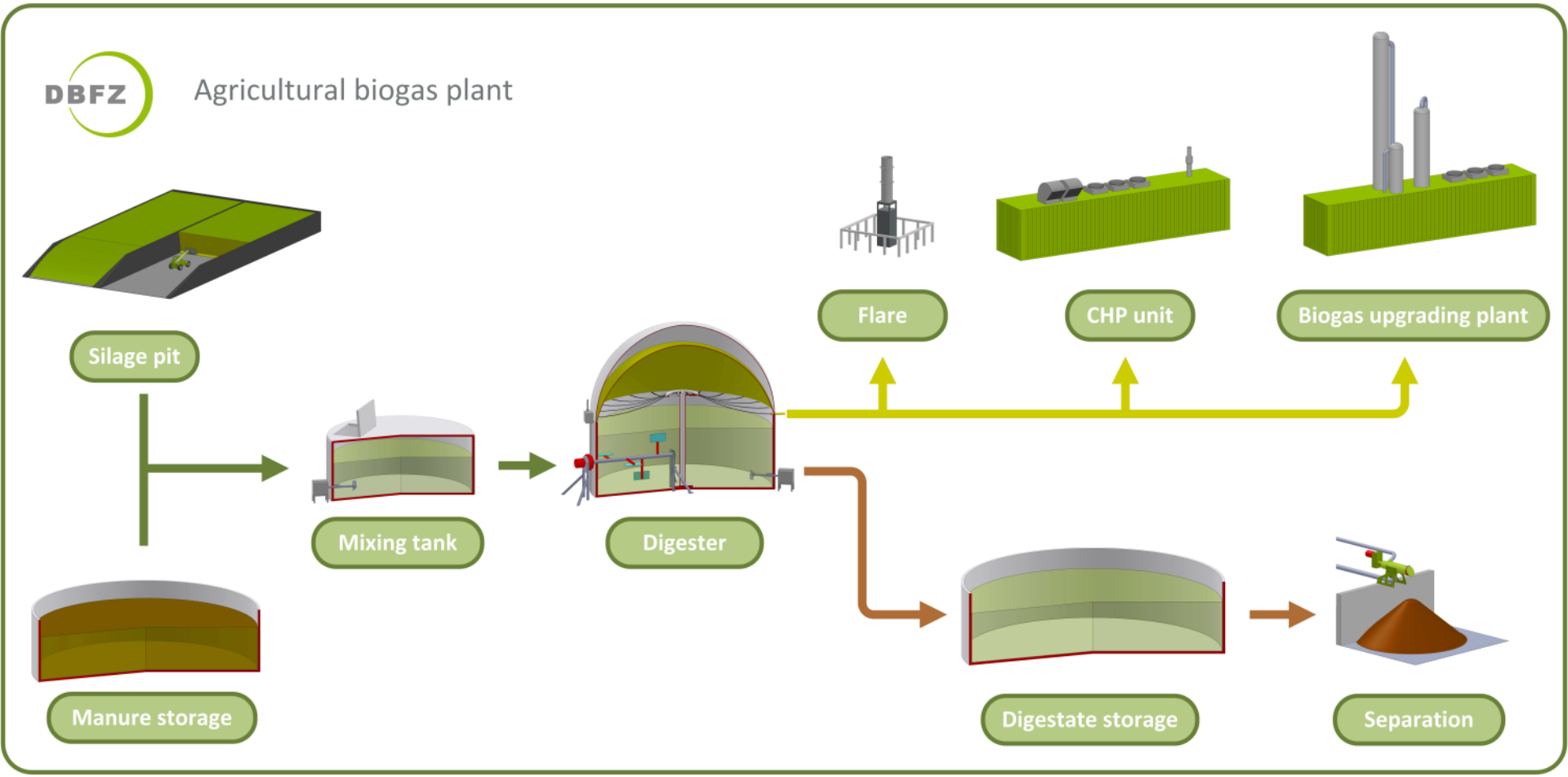

Emissions can be caused by construction or operation

Measurement of emissions - challenges

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Sources:

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

Methods:

Two major strategies (one site and 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

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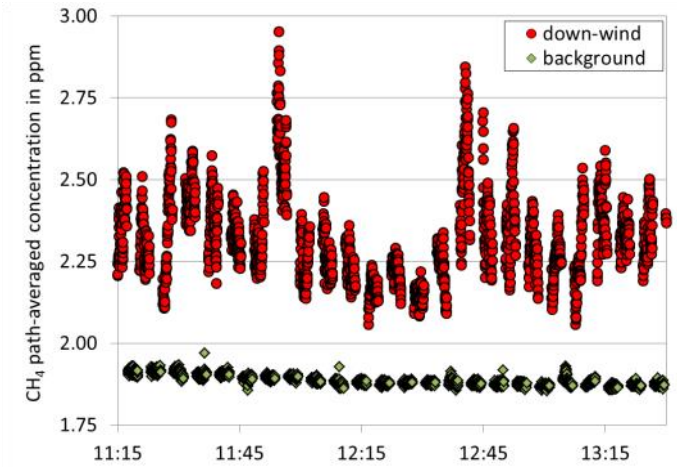
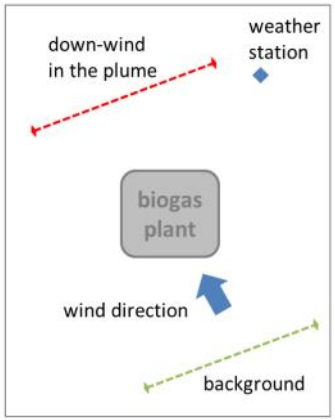
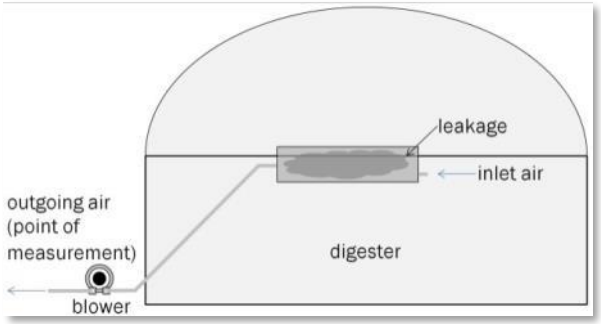
Remote sensing





Onsite, single source measurement



All pictures: DBFZ

Pro and cons

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	On site - single source measurement	Overall plant measurement
Strengths	Identification and quantification of single sources Emission rates of single sources are analysable and direct mitigation strategies can be deduced Low detection limit (single source and total emission rate) Independent of weather conditions Effort adjustable to the requirements	Long-time measurements with high resolution possible No influence on plant operation Time effort quite independent from plant size All emissions sources are recorded Time variant emissions are detectable during long term measurements
Constraints	Time variant emission sources are difficult to identify Unknown and diffuse sources are not included High effort on large plants with many digesters Influence of measurement on emissions (e.g. chamber methods)	No identification of single sources possible Highly dependent on wind conditions and topology around the plant Influence of the uncertainties of dispersion models and/or atmospheric mixing Difficulties of separation of other sources nearby (e.g. barns)

On site - single source method procedure

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1. Identification of emission sources;
2. Setup for emission sources with respective methods for:
    - Digestate storage;
    - Leakages;
    - Upgrading units;
    - Pressure relief valves;
    - Exhaust pipes (e.g. CHP units or gas collection systems);
    - Open (in case no centralized air collection system available) post composting windrows.
3. Determination of flow rate;
4. Determination of concentration of target gas;
5. Calculation of emission rates;
6. Summation of all sources.

Some results and trends - Leakage identification

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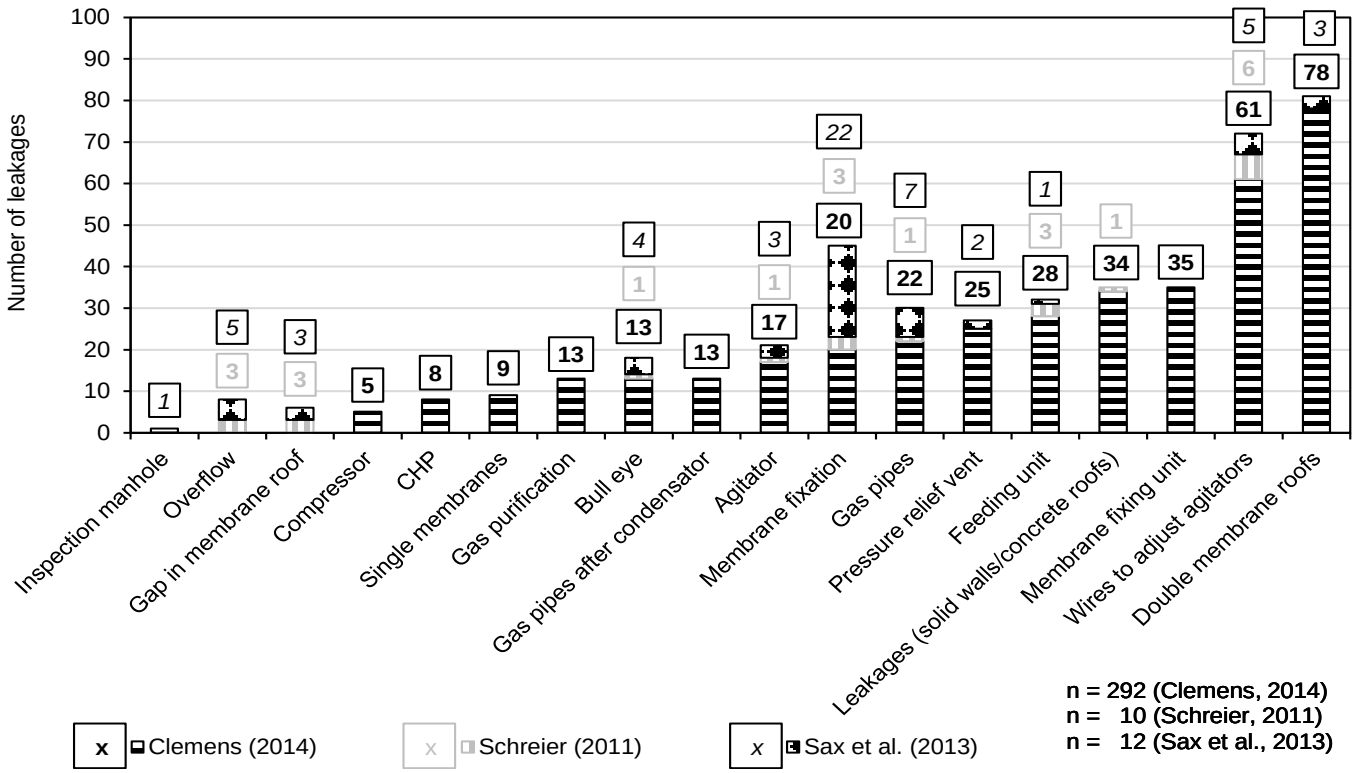

- Almost every site shows leakages of varying emission rates
- Transfer of measured leak emissions (or any “no standard operation) to longer periods of time (e.g. for LCA or certification) is difficult

Double layer air inflated membrane roofs

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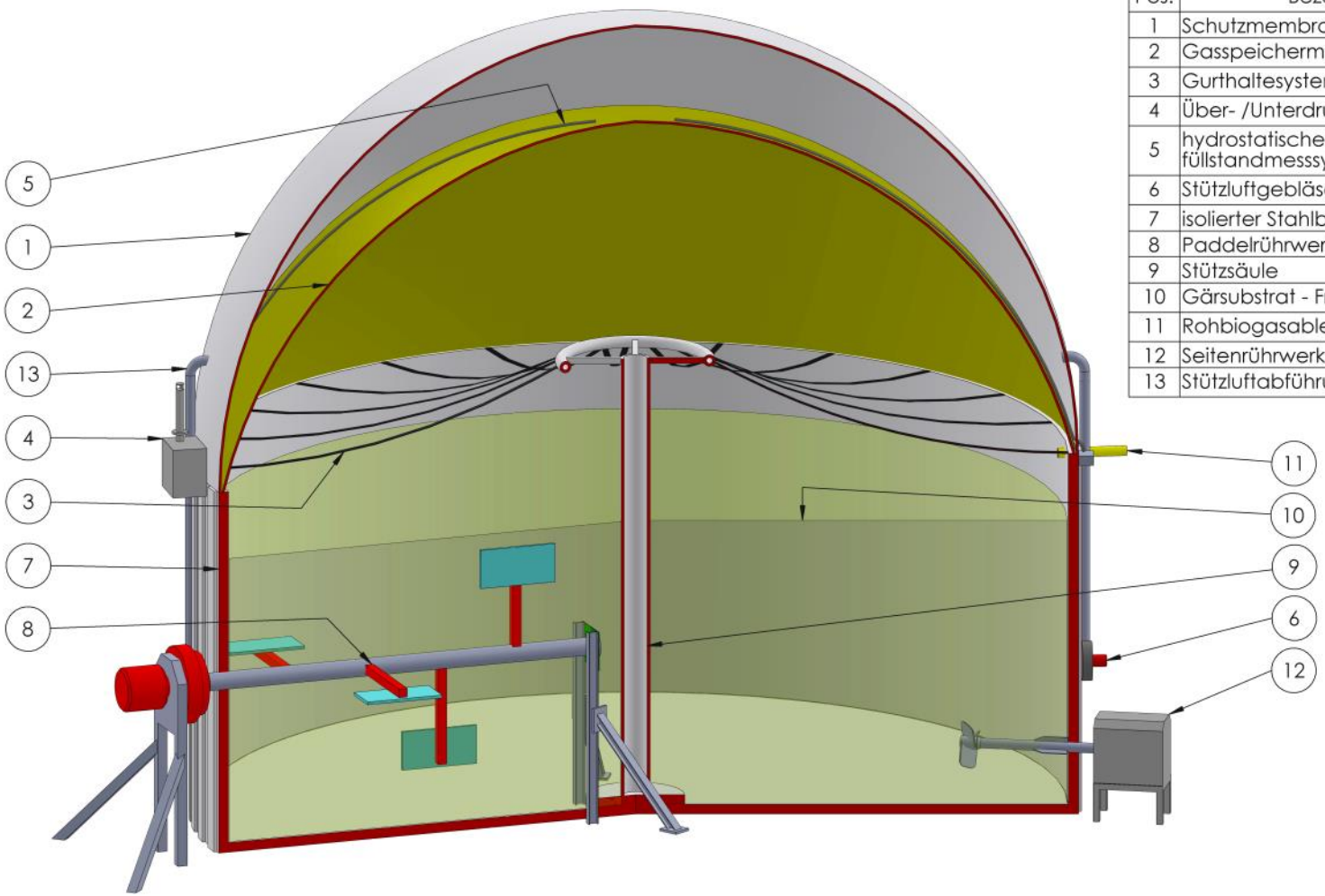

Pos.	Bezeichnung
1	Schutzmembran
2	Gasspeichermembran
3	Gurthaltesystem
4	Über- /Unterdrucksicherung
5	hydrostatisches Gasspeicher-füllstandmesssystem
6	Stützluftgebläse mit Stauklappe
7	isolierter Stahlblechmantel
8	Paddelrührwerk
9	Stützsäule
10	Gärsubstrat - Freispiegel
11	Rohbiogasableitung
12	Seitenrührwerk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

Gas storage

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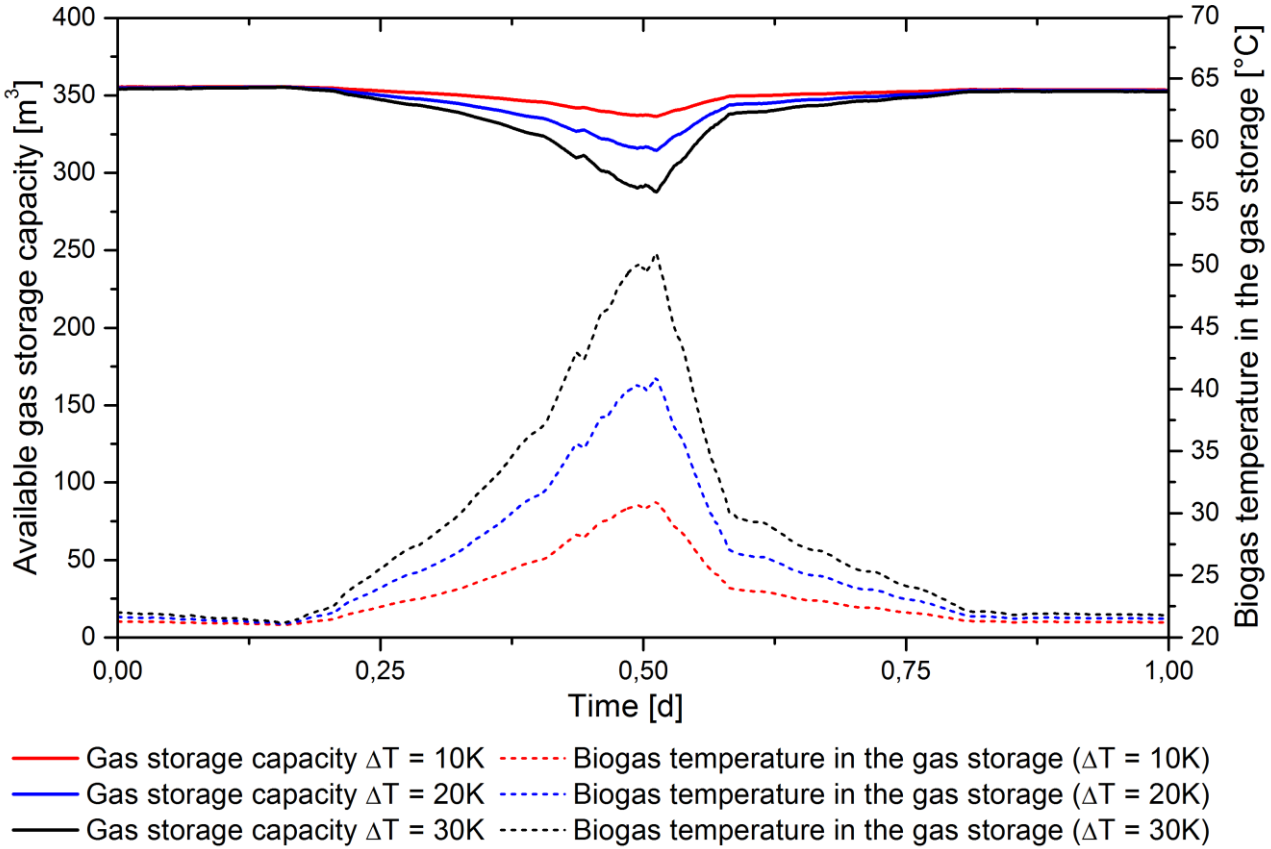

30 K temperature change results in 20 % volume increase (gas extension and water vapour)

Weather and overpressure release events

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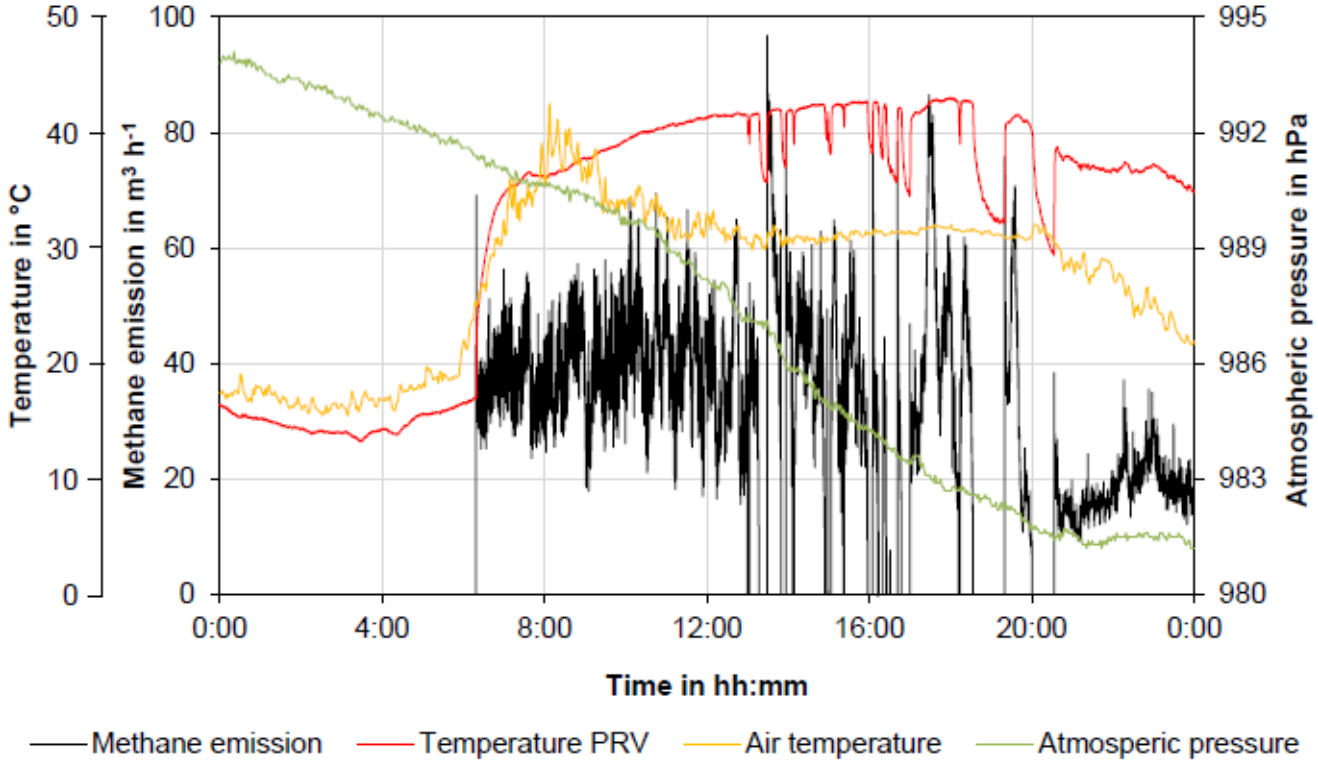

Atmospheric conditions may result in pressure relief events

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.

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

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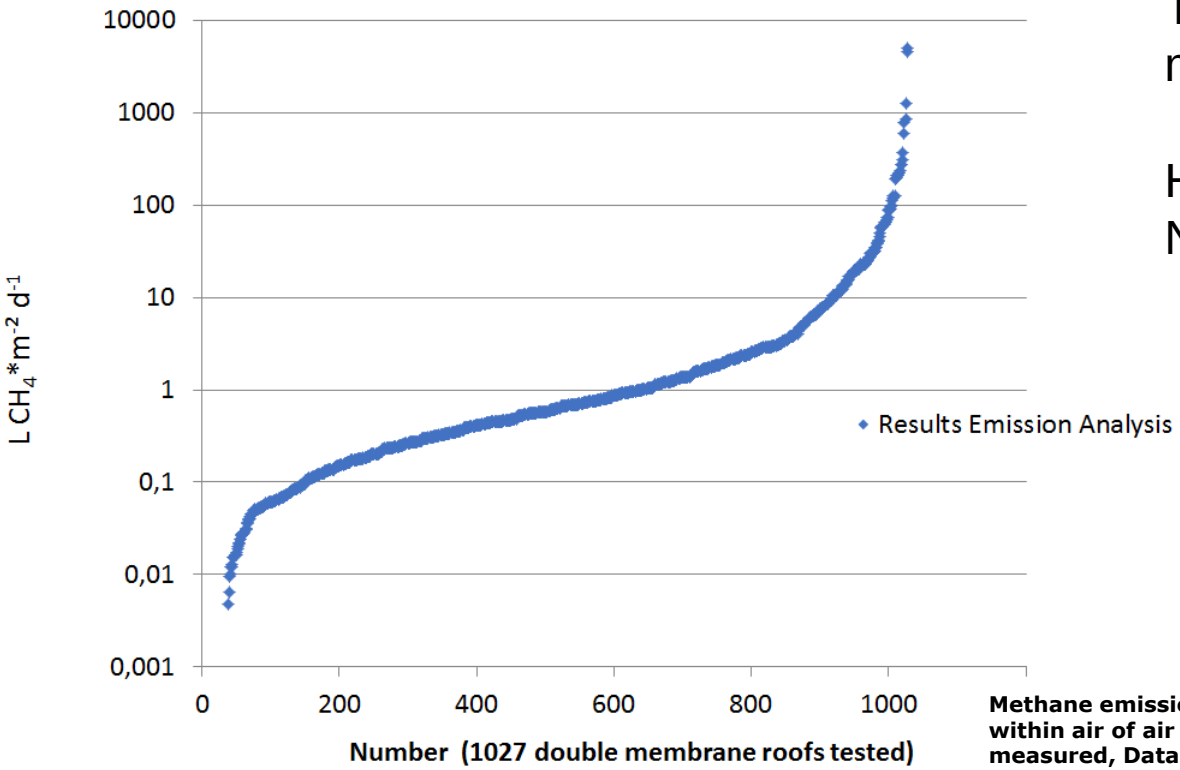

Threshold for diffusion of membranes in Germany:

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

Post treatment

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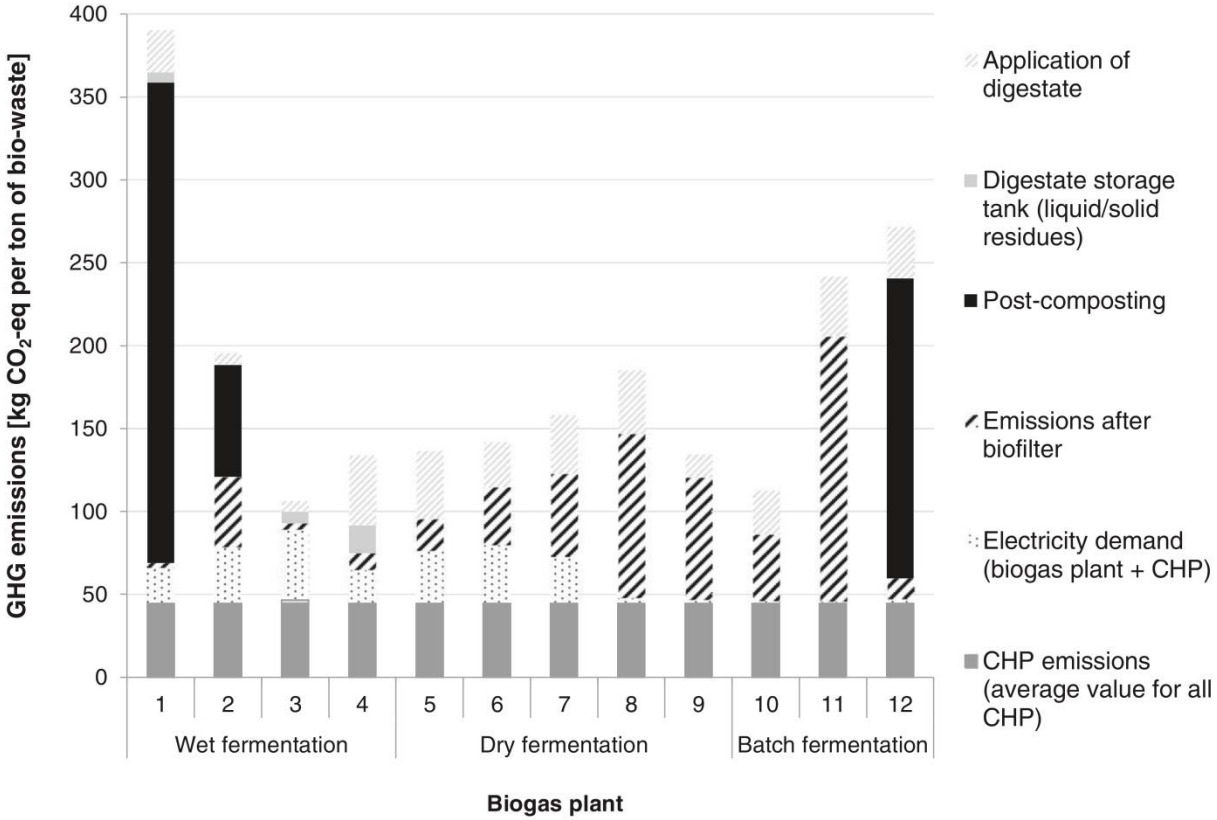

- Post composting can be large source of emissions,
- Sufficient aeration and oxygen supply during composting reduces emissions

DANIEL-GROMKE, J., LIEBETRAU, J., DENYSENKO, V., KREBS, C. (2015), Digestion of bio-waste - GHG emissions and mitigation potential, Energy, Sustainability and Society, Volume 5:3, doi: 10.1186/s13705-014-0032-6

Digestate storage

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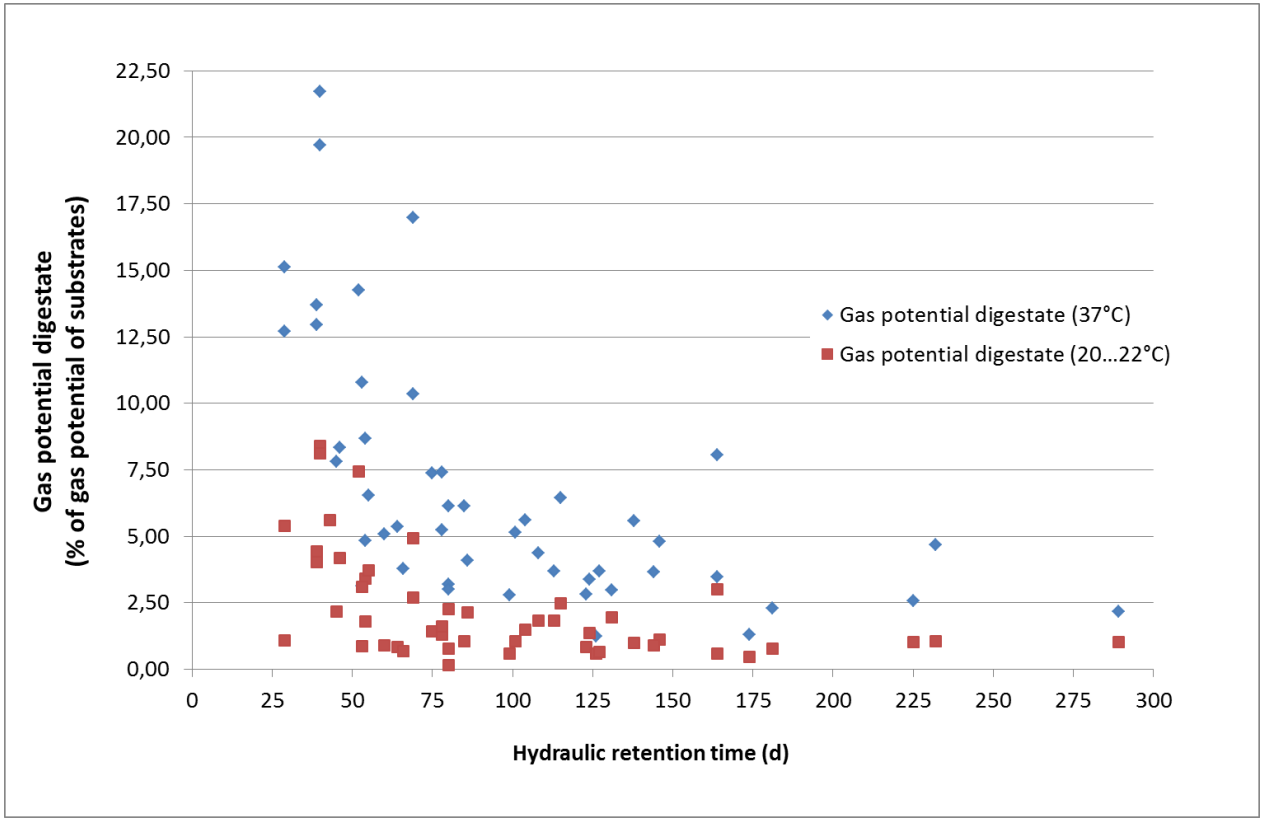

Difficult to analyse with single measurement due to changing temperature and filling level

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).

Emission sources

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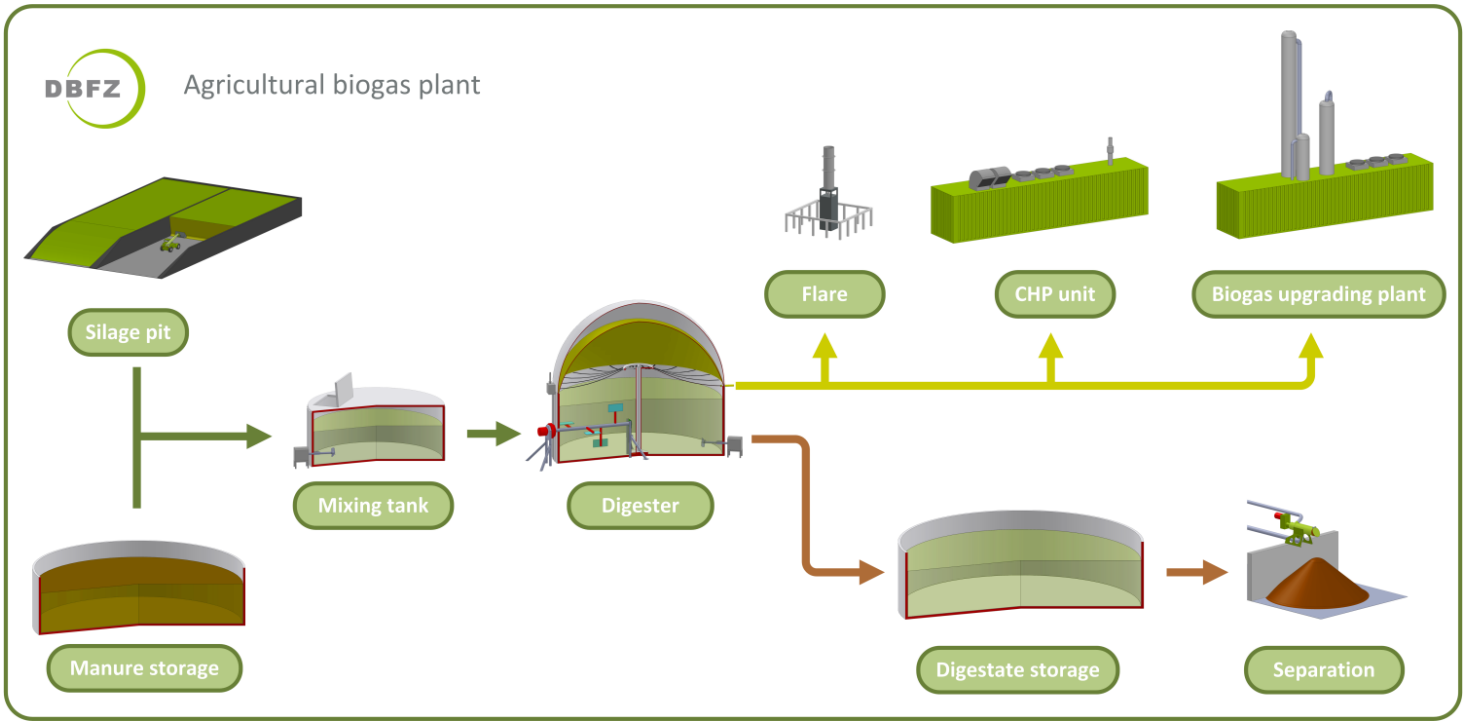

- **Manure digestion reduces emissions, co digestion to a certain degree**
- **When gas (emission) potential of manure equals gas (emission) potential in the digestate (assuming open storage) emission reduction is zero (equal methane conversion factor manure and digestate)**

Manure in co – digestion systems

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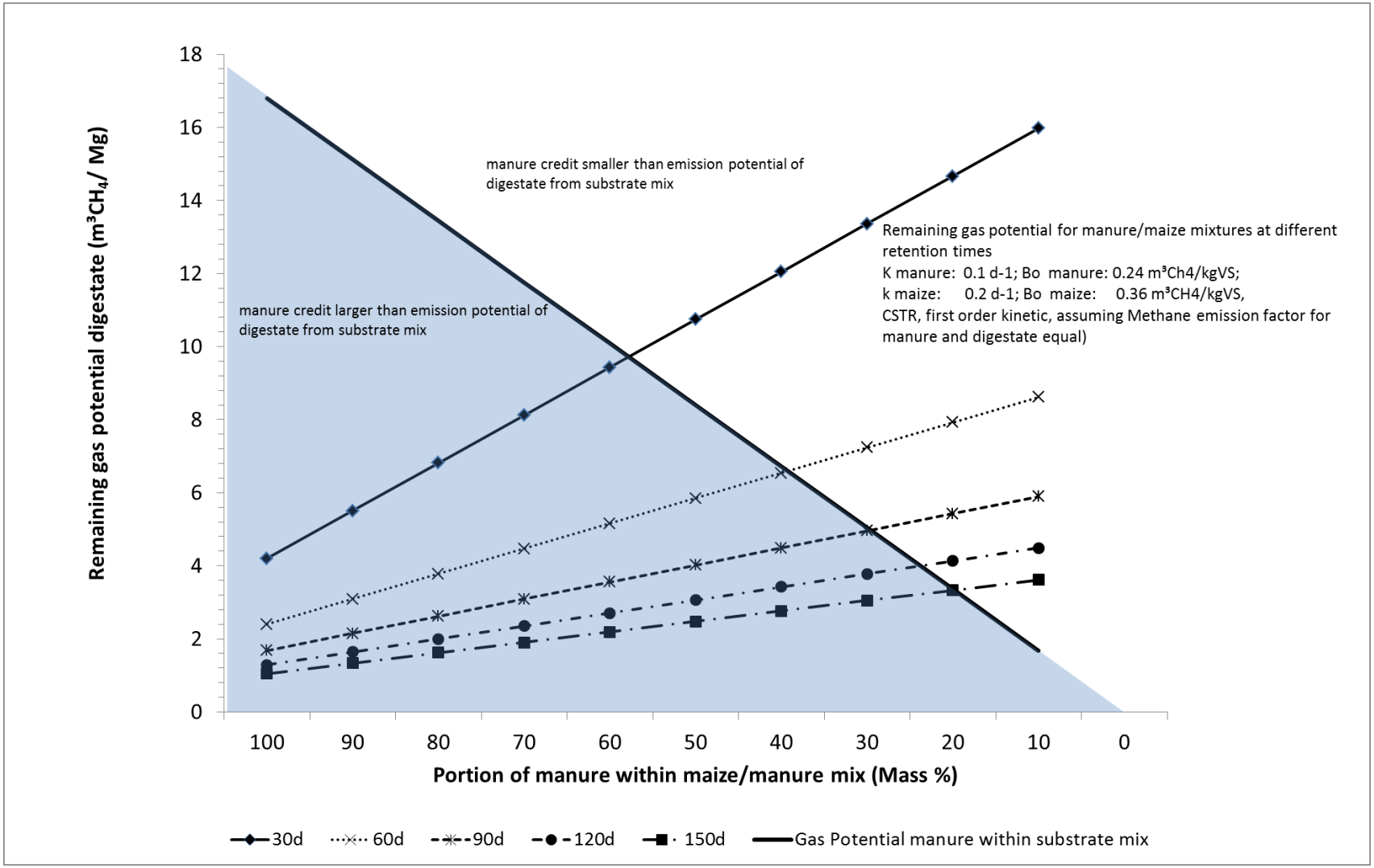

Manure in co – digestion systems

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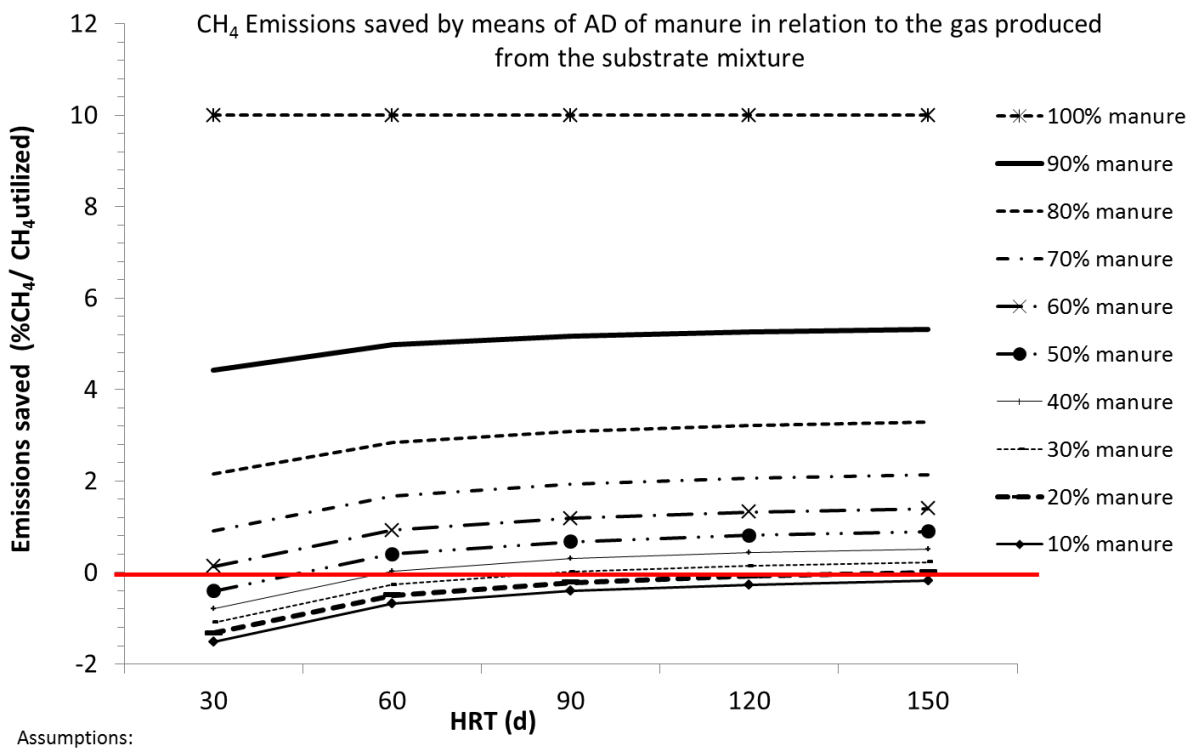

Assumptions:
Emissions from open digestate storage after given retention time, Equal methane conversion factor manure and digestate (10%)
K manure: 0.1 d^{-1}; Bo manure: 0.24 $m^3Ch4*kgVS^{-1}$; k maize: 0.2 d^{-1}; Bo maize: 0.36 $m^3CH4*kgVS^{-1}$, CSTR, first order kinetic,

Manure fraction is crucial, effect of retention time not as pronounced

Biogas and natural gas CHP

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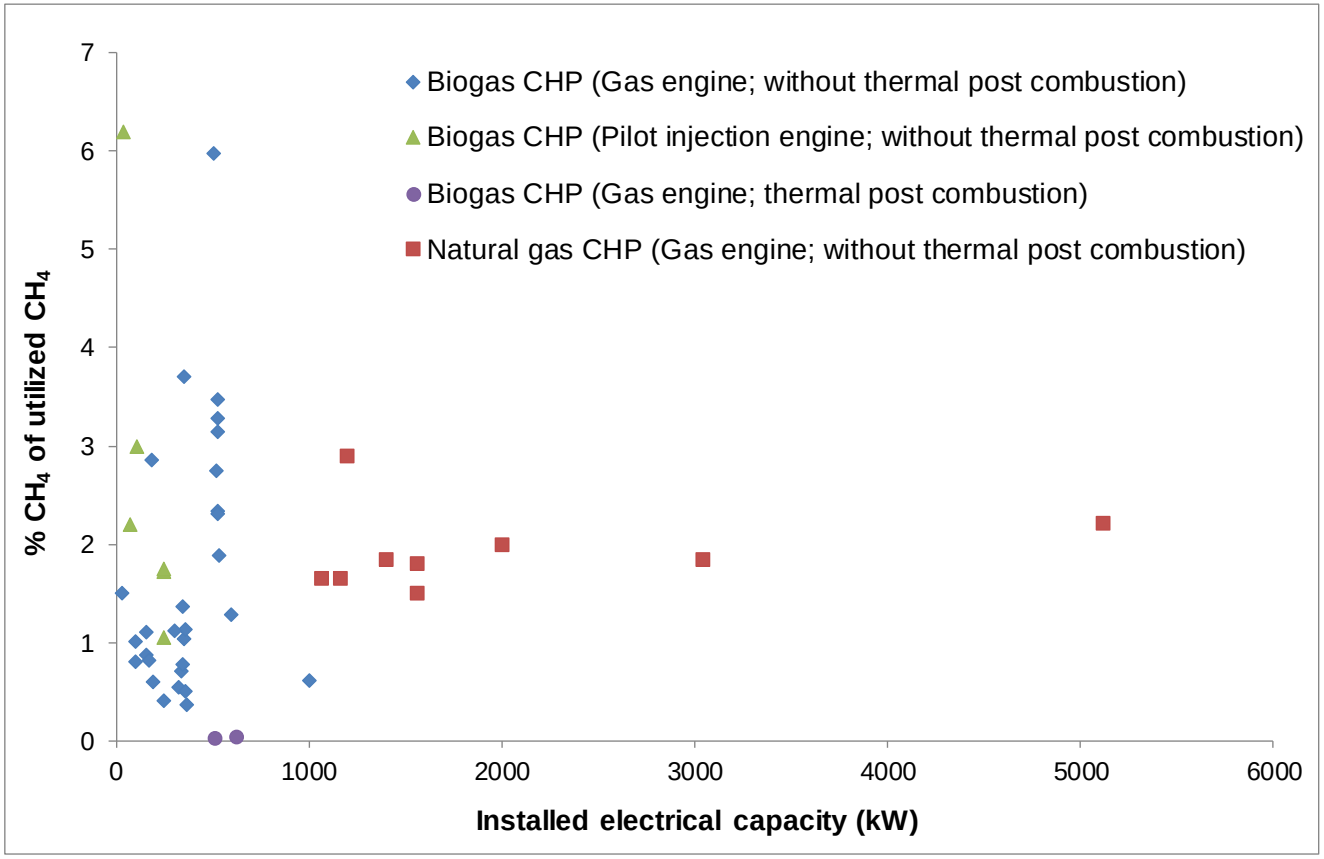

Methane emissions from CHP units operated with biogas and natural gas (Liebetrau, 2013a; Aschmann, 2014, Kretschmann, 2012; van Dijk, 2012)

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

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

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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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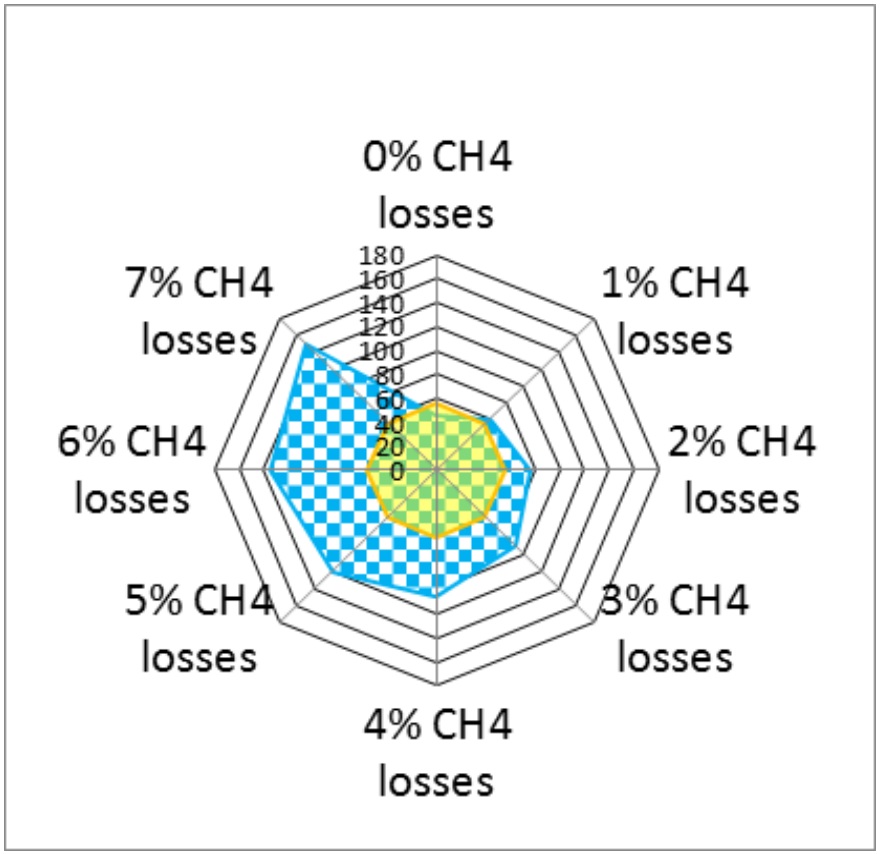

100% maize silage

0% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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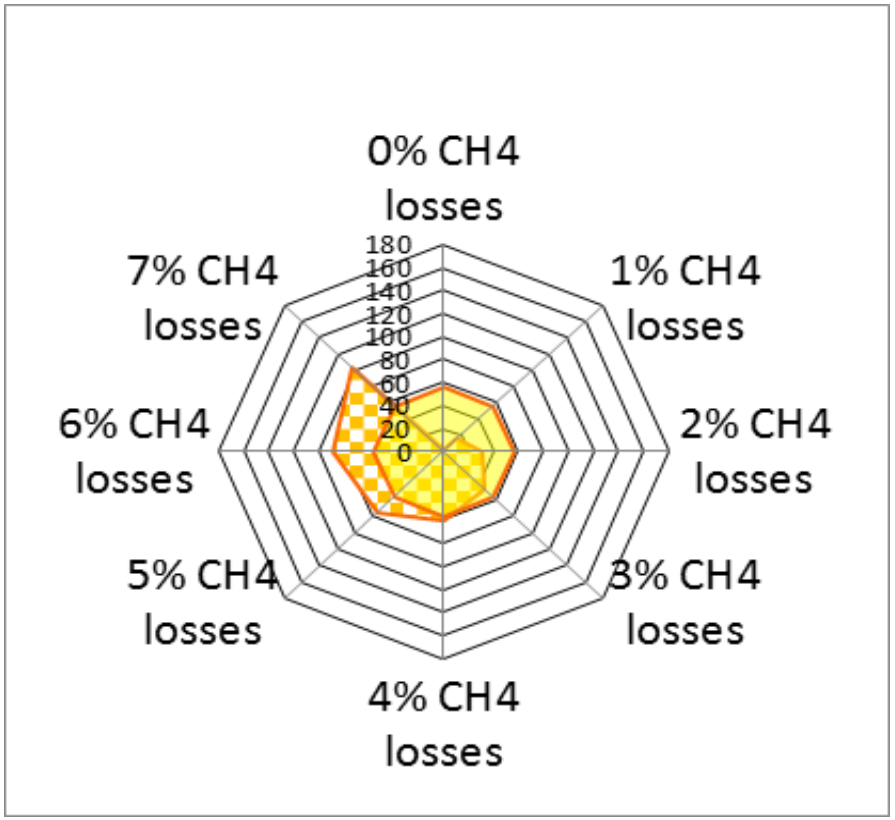

100% organic waste

0% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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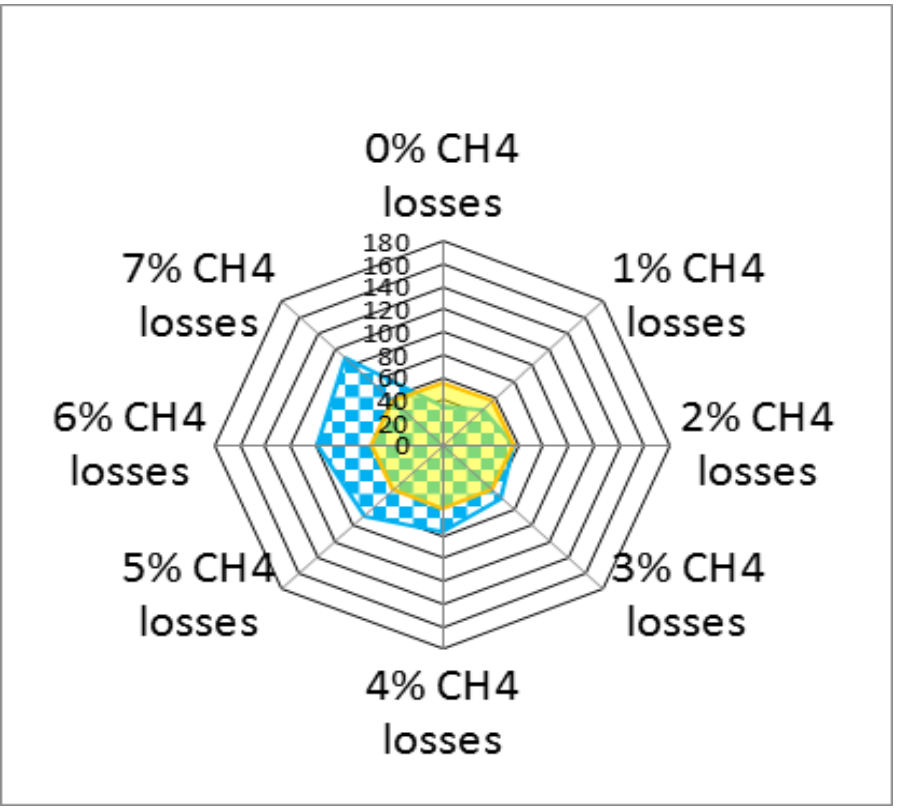

100% maize silage

40% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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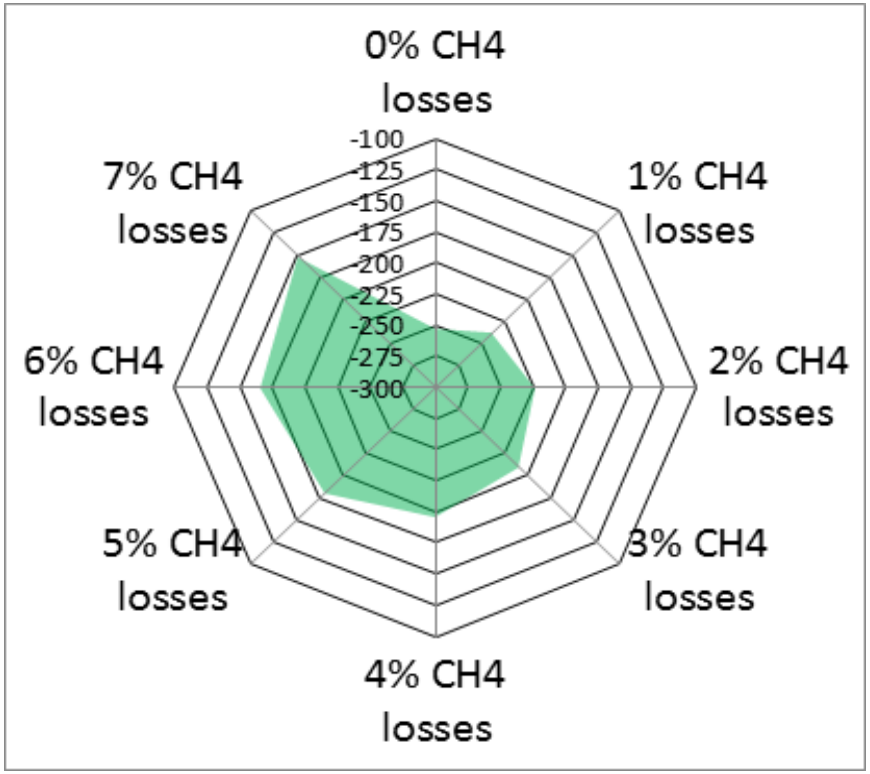

100% Manure

0% Heat utilization

5% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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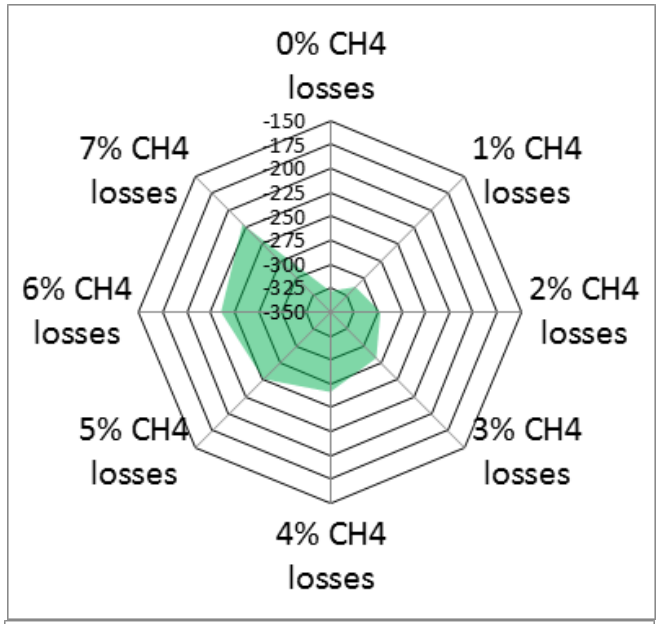
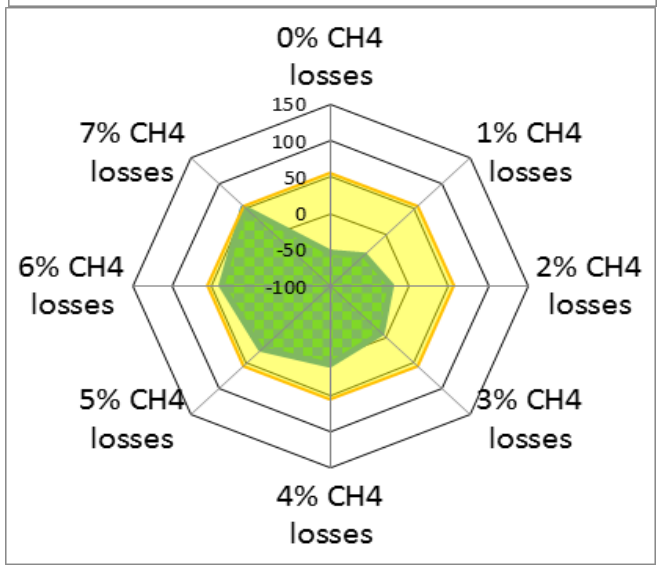


100% Manure

0% Heat utilization

10% electrical parasitc consumption



80% Manure/20% Maize silage

0% Heat utilization

10% electrical parasitc consumption

GHG Balance compared to 30 % FFC

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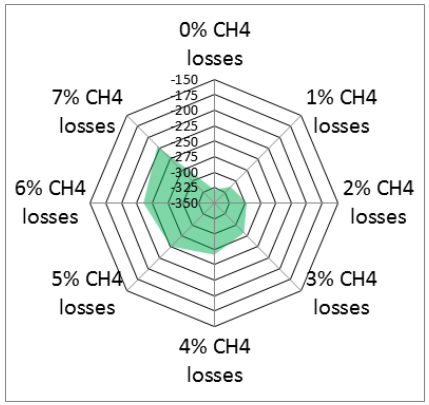
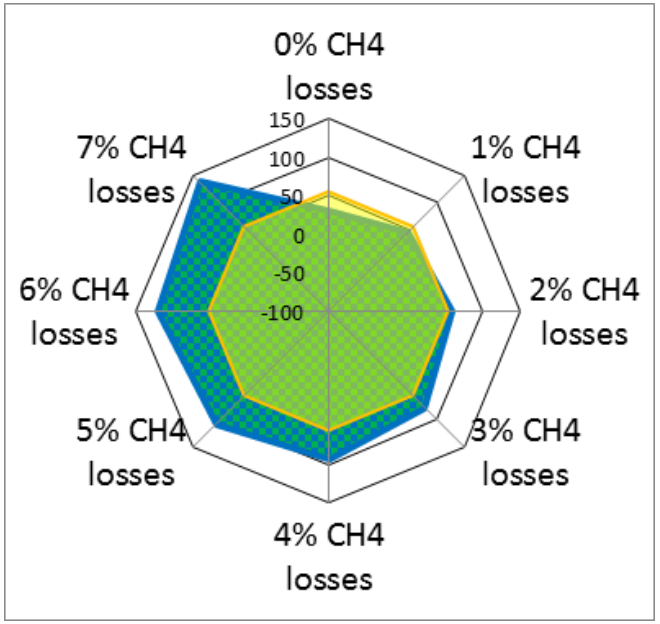
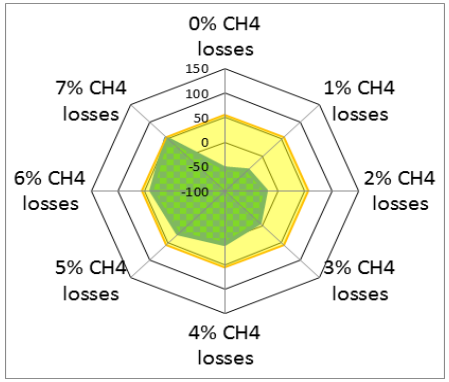


100% Manure

0% Heat utilization

10% electrical parasitc consumption





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

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- Gas tight cover of digestate storage or extensive degradation of the substrate before storage
- Digestate post treatment: apply sufficient oxygen supply
- CHP: frequent engine maintenance (Option is also post-treatment technology for the exhaust)
- Frequent leakage detection
- Gas handling:
  - Operation of membrane gas storage systems with filling level of 50 % under normal operation
  - Automated flare operation (dependent on filling level of gas storage) (where necessary: monitoring of pressure relief vents)
  - Adequate dimensions of gas transport pipes, controlled air supply for air inflated roofs, controlled gas exchange within storages

Conclusions

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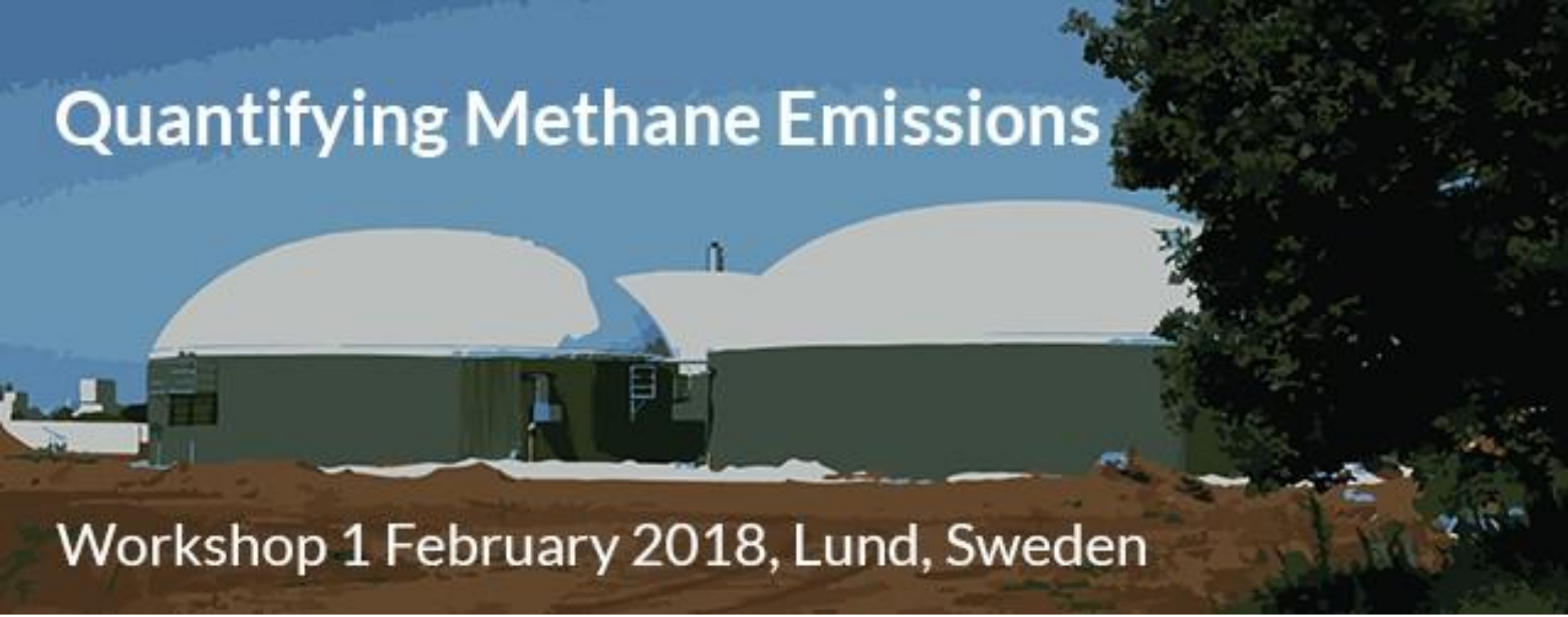
- More and more results on single plant evaluations, however limited knowledge about the general situation (different methods and individualized plants)
- Results of measurements difficult to compare since methods, measurement devices and documentation not standardized
- Method harmonization necessary
- 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



Target group: Biogas plant owners and operators, plant personnel, policy makers, researchers.

Venue: Elite Hotel Ideon, Scheleevägen 27, Ideon Science Park, Lund, Sweden.
Date: 1 February 2018.

Last registration date 18 January 2018.
Course fee 80 EUR (VAT not included) including lunch.
Networking dinners will be arranged 31 January and 1 February at self-cost price.

More Information and Registration:
https://www.sp.se/en/training/Sidor/MetHarmoWorkshop.aspx

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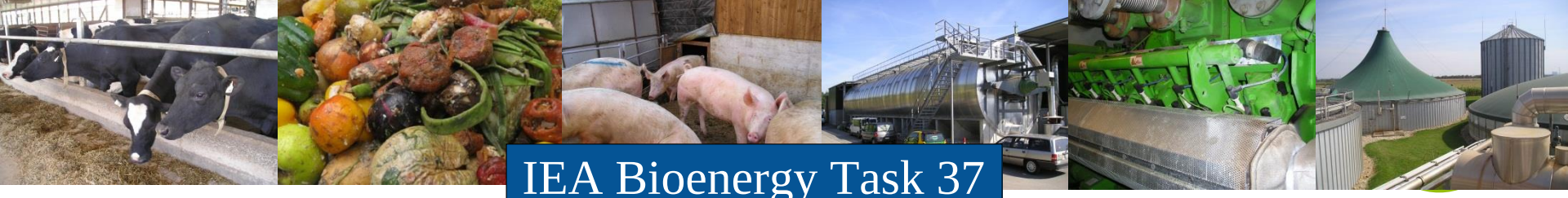
Acknowledgements:

Arthur Wellinger of the European Biogas Association for reviewing this report.

Tanja Westerkamp and Tina Clauß for contributions and Antje Krücken for formatting and counterchecking.



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The report is available on the website of IEA Task 37:
http://task37.ieabioenergy.com/technical-brochures.html

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Thank you for your attention

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