Deutsches Biomasseforschungszentrum
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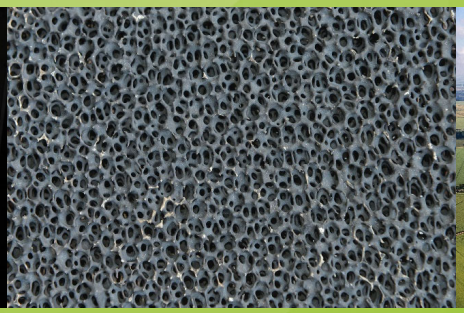
Quantifying methane emissions from Biogas plants: Insights from on-site measurements

Julian Matlach and Lukas Knoll



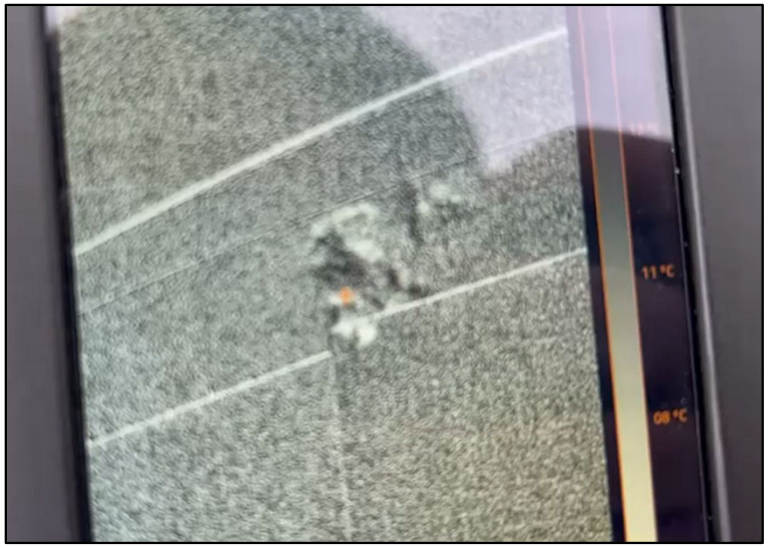
Webinar on methane emissions, IEA Task 37, 19.02.2026

Agenda

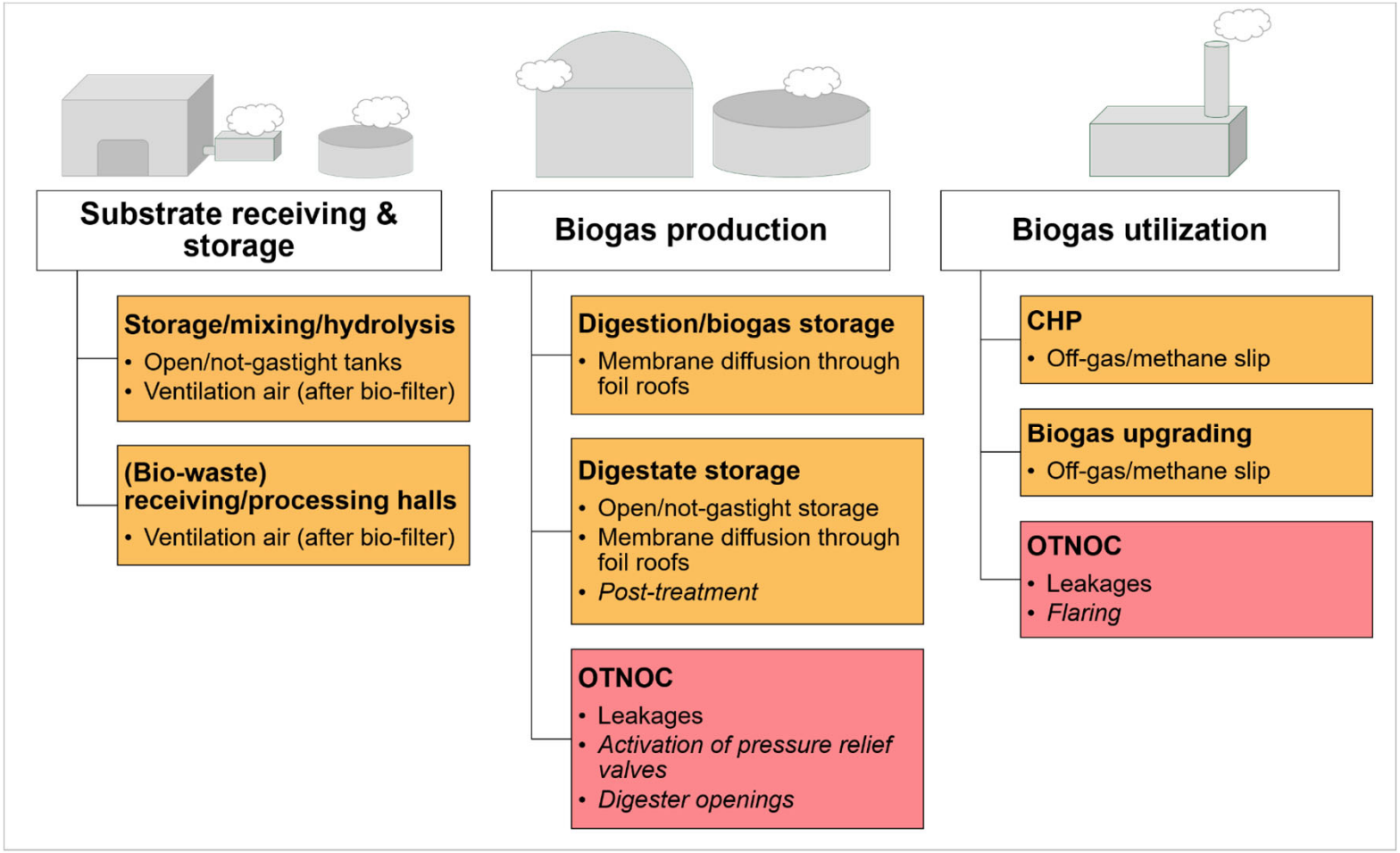
- Background and national regulations
- Potential emission sources
- Emission measurement methods
- Experiences and results of emission measurements at biogas plants
- Options to reduce the methane emissions

Background and national regulations

- Leaks pose a risk to operational safety (LEL 4.4% v/v and UEL 16.5% v/v)
    - leak tightness inspections are required at least **every three years** in accordance with the Industrial Safety Ordinance (BetrSichV) and the Federal Immission Control Act (BImSchG)
- In addition to causing ecological harm through the release of climate-relevant methane (GWP100=27 CO_2eq)
- leakages in a biogas plant also represent economic losses



Potential emission sources



OTNOC: other than normal operating conditions

Emission measurement approaches

On-Site Approaches

- Direct measurement at emission sources within the biogas plant
- Point sources (e.g., pressure relief valves, flare, CHP exhaust)Area sources (e.g., digestate storage, silage clamps)
- Component-level detection (valves, flanges, fittings – LDAR)

- **Off-Site Approaches**
- Quantification of total facility emissions from outside the plant
- Ambient air measurements and remote sensing techniques
- Top-down emission assessment

Emission measurement approaches

On-Site Emission Assessment

Step 1: Leak Detection

Screening & Localization

- OGI Camera
- Methane Laser Detector

- Identify Leak Sources
- Pinpoint Emissions

Step 2: Quantification

Emission Measurement

Enclosed Chamber

Flow Measurement

QOGI Camera

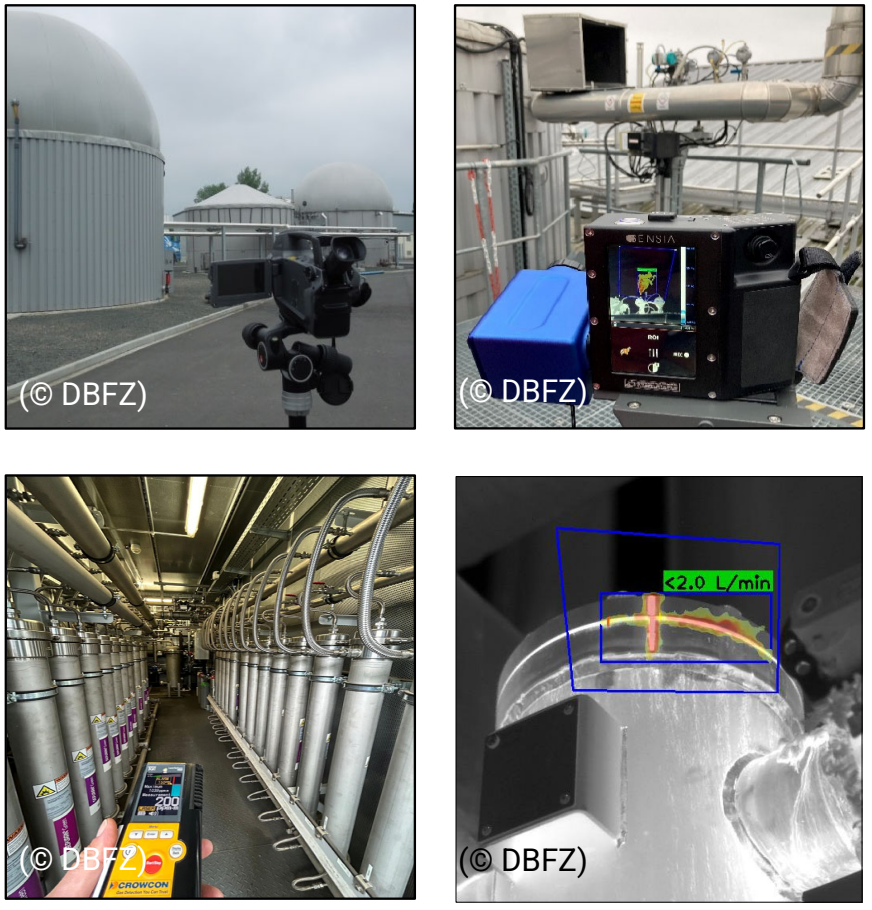
- Measure Gas Flow & Concentration
- Calculate Emission Rate
- Quantify Methane Emissions

Source-Specific Emission Rates & Mitigation Actions

Leakage detection

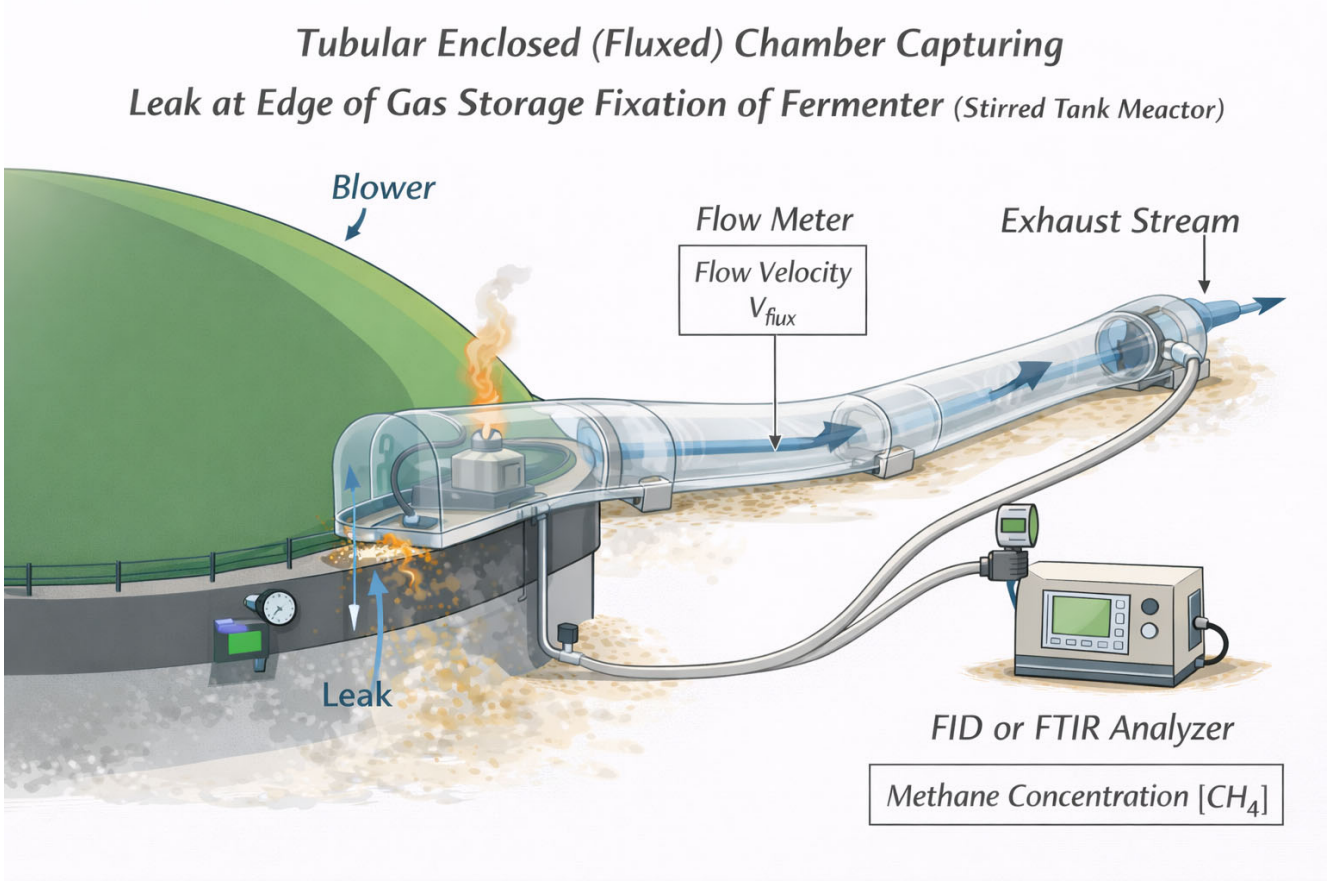
Single Source Analysis (on-site approach)

- Identification of individual sources
  - OGI camera (VDI 4321)
  - methane laser (EN 15446)
- Setup of the measuring points depending on the source type
- Quantification of diffuse leakages with QOGI-camera
- Summation of the individual sources to the total methane load of the plant



OGI – Optical Gas Imaging

Basics of emission Quantification



Concentration

+

Flow

=

Emission rate

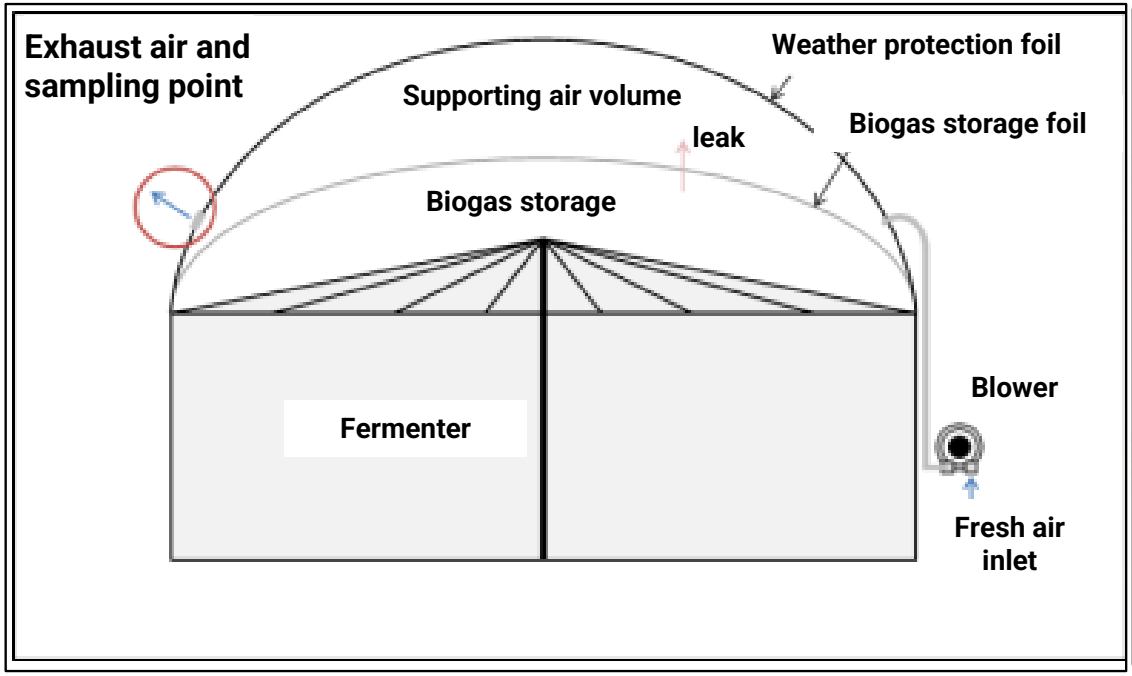
Quantification measurements

Channelled sources

- Off-gas from gas utilization units (CHP or RTO)
- Encapsulated emission sources, air collection system, directed to a biofilter,
- Sampling at the nozzle of the line via heated sampling line
- Continuous measurement: flame ionization detector (FID)
- Discontinuous measurement: evacuated vials
- European guidance (EN ISO 25140, EN ISO 25139, EN 15259, ISO 16911-1)

Supporting air measurements

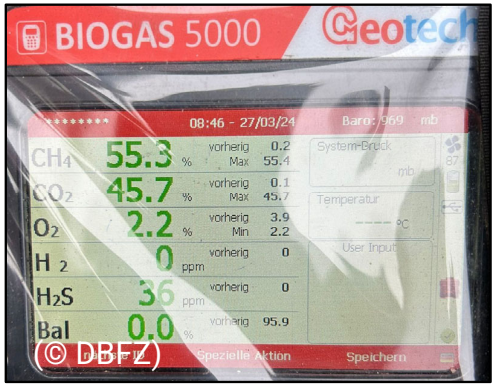
- Enclose the exhaust air point and measure volume flow (VDI 2066 Blatt 1, VDI 4200 and DIN EN 15259)
- Discontinuous sampling with evacuated vials → Gas chromatography (DIN EN ISO 25139)



Quantification of leakage emission

Options to determine the emission flux from leakages

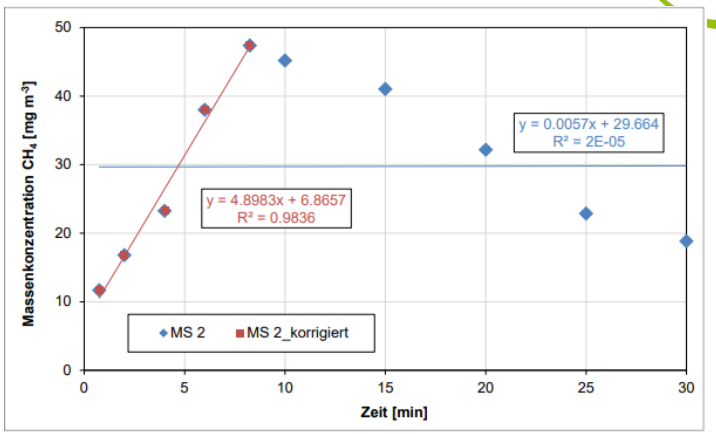
- Gas concentration (is known from gas analysis) (% v/v) + measured leakage flux ($l\ h^{-1}$) = CH_4 leakage as a emission rate ($l\ h^{-1}$)
- Open dynamic chamber method: Enclose and ventilate the leakage (ppm or $mg\ m^{-3}$) with a defined volume flow ($m^3\ h^{-1}$)→ results in a methane mass rate ($mg\ h^{-1}$)
- VDI 4285 Blatt 1

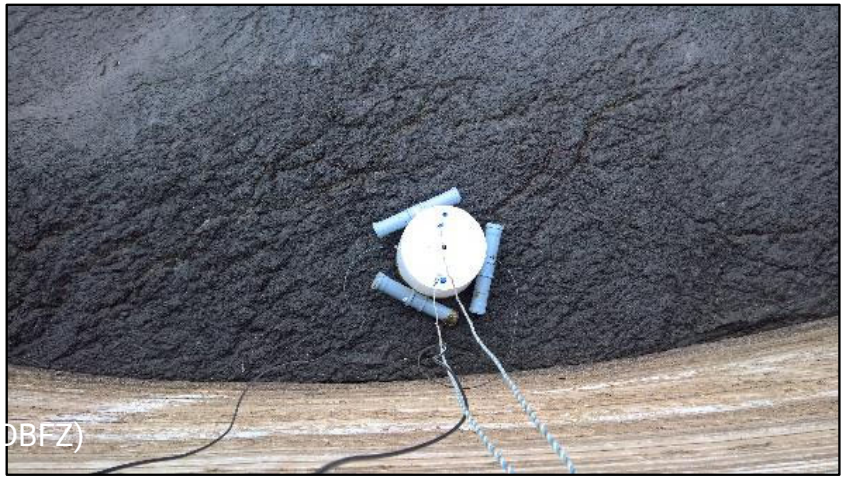


Static chamber method

Emission measurement at surface sources (open storage systems for manure or digestate)

- the methane concentration in the volume of the static chamber increases linearly
- Continuous measurement of CH_4 with a flame ionization detector (FID) → results in specific surface EF (mg CH_4 m^{-2} h^{-1})
- Volume-specific EF (mg CH_4 m^{-3} h^{-1}) calculated with a volume-to-area ratio (m^3 m^{-2})

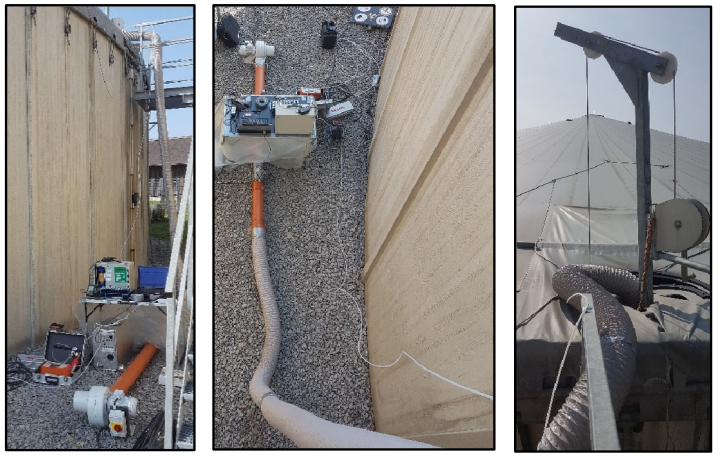




Air injection method

Emission measurement at surface sources (non-gastight covered storage systems)

- Ventilation of non-gas tight storage with a defined volume flow ($m^3\ h^{-1}$)
- Continuous measurement of CH_4 with a FID or FTIR and discontinuous sampling with evacuated vials for CH_4 →GC analysis in lab
- CH_4 concentration equilibrium is modeled using an equation ($mg\ m^{-3}$)



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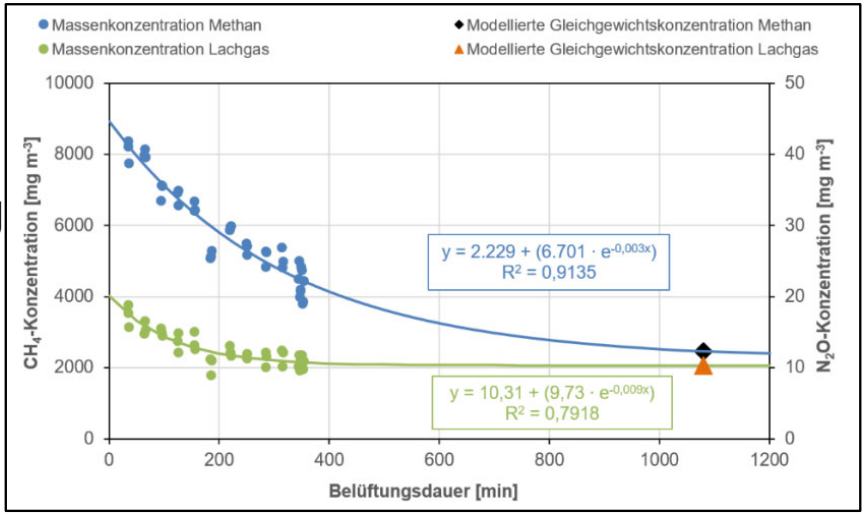
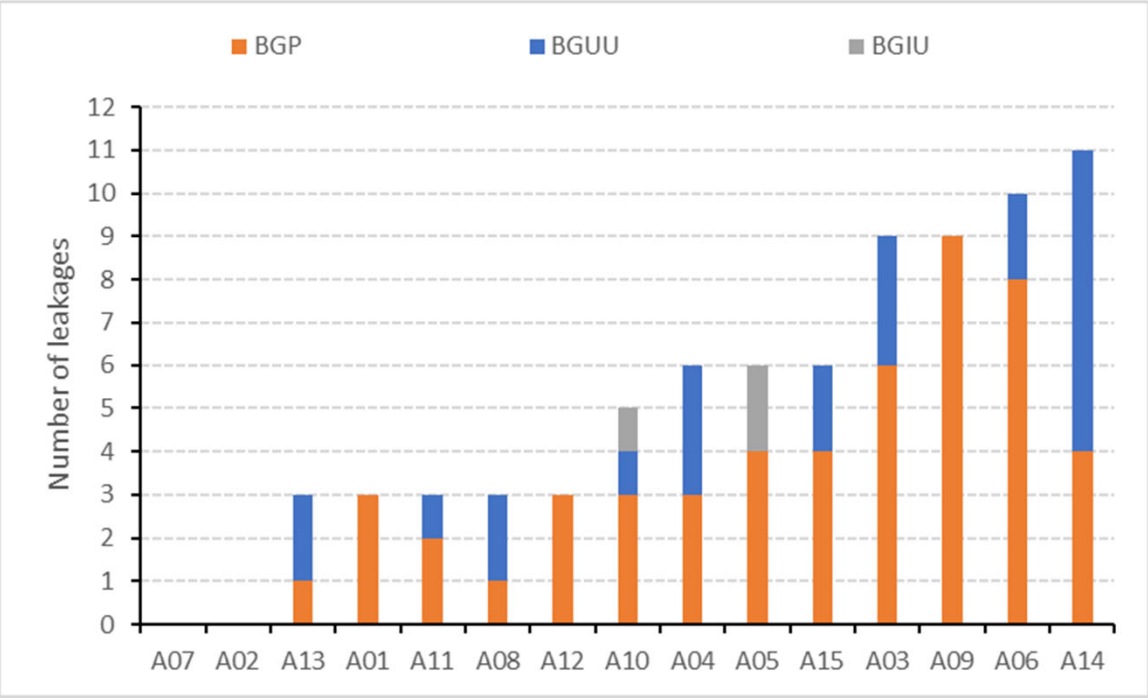


Experiences and results of emission measurements at biogas plants

Matlach and Knoll, IEA Task 37 Webinar, 19.02.2026

EmMinA: Leak detection



In total: 77 leakages at 15 plants:

BGP: On average 3.5 leakages per plant

- Gas pipes, pipe penetration (10x)
- Pressure relief valve (leakage) (10x)
- Wires to adjust agitators (6x)
- Increased CH_4 conc. in the supporting air (4x)

BGUU: On average 1.5 leakages per plant

- Flanges, valves, ball valves (14x)
- Compressor (3x)

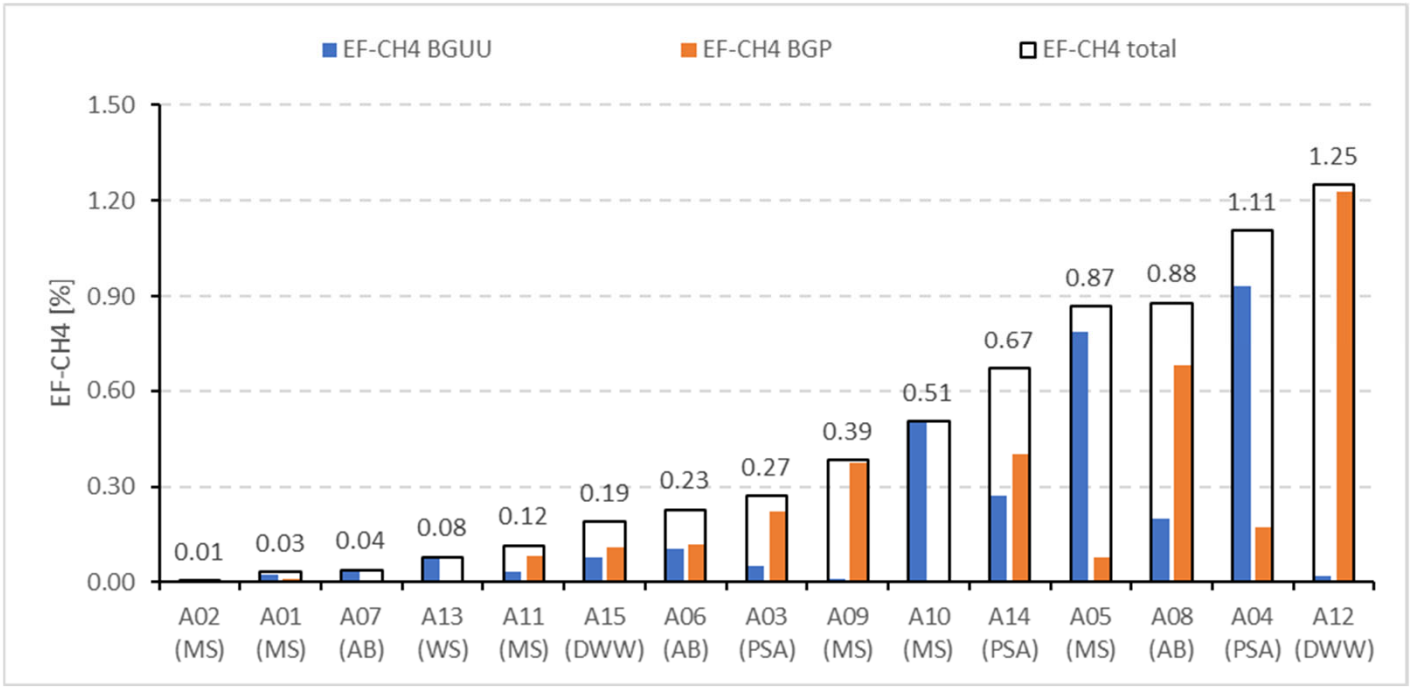
BGIU:

- At one plant active overpressure blower

BGP: Biogas plant
BGUU: Biogas upgrading unit
BGIU: Biogas injection unit

- On average 5 leakages were found per plant

Total emission factor per plant



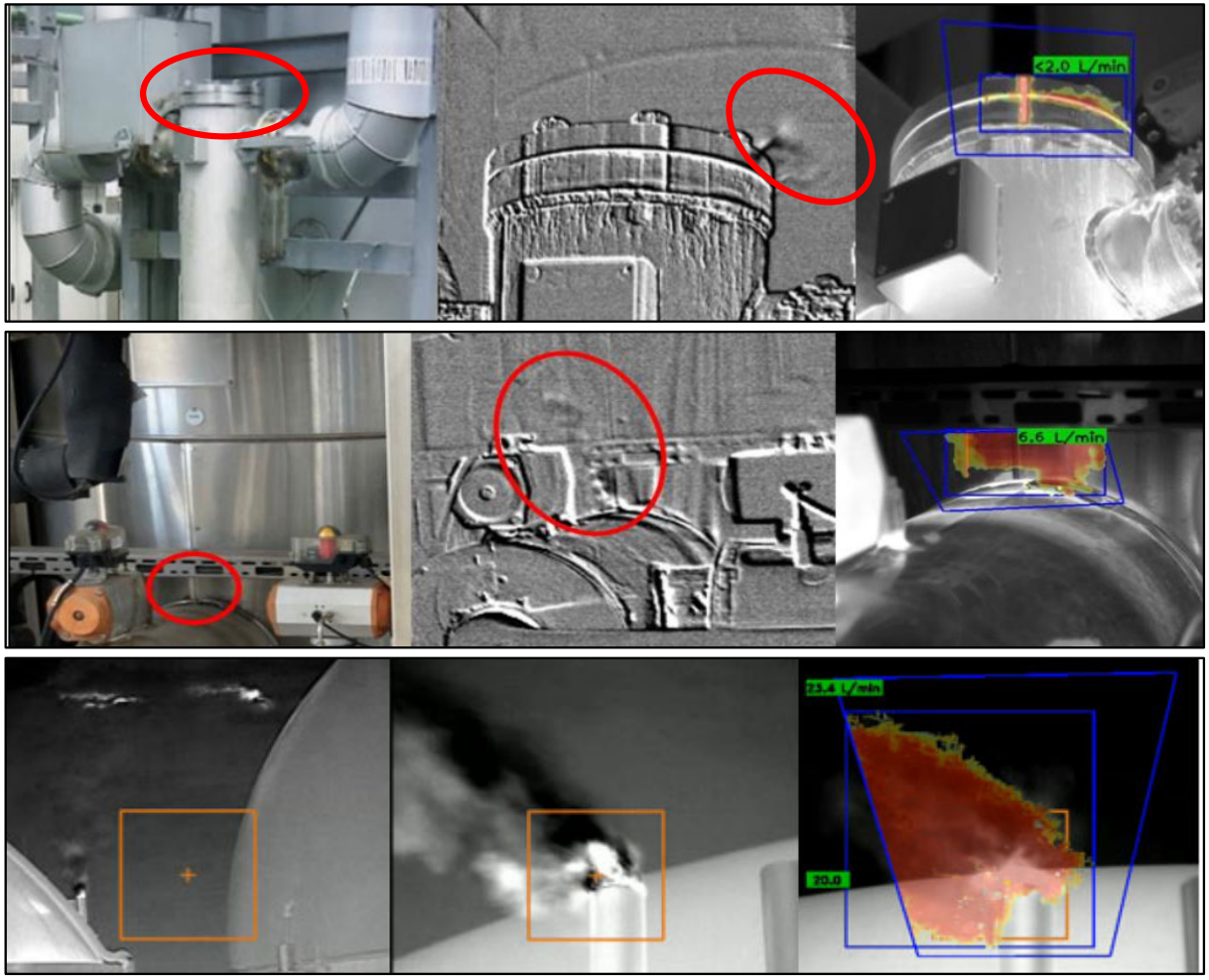
- CHP emissions not considered
- All plants had covered digestate storage tanks

- A12: 2 leaks at membrane seal
- A04: RTO not in operation
- A05: 80% of emissions through active overpressure blower

MS: Membrane separation
PSA: Pressure swing adsorption
AB: Amine scrubbing
DWW: Water scrubbing

➢ **Average total EF-CH_4: 0,44 % (n=15)**

Leak detection and quantification with QOGI



- Small leakage at a flange
  <2 L/min
- leakage at a valve
  6.6 L/min
- Active pressure relief valve
  20 L/min

Methamin

Minimizing methane emissions during the storage of farm manure

Objectives

- Long-term emission measurements
- Ventilation method (performed monthly)
- Dimensioning and design of a biological methane oxidation filter

Results:

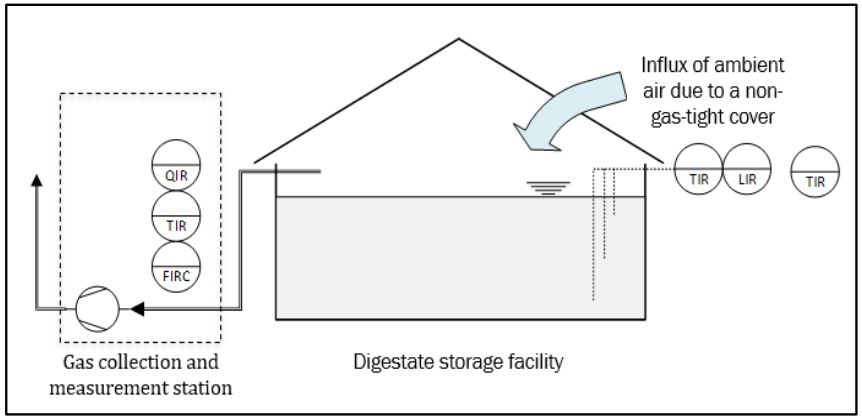
- Min/Max manure temp.: 7 – 20°C
- Methane emissionen: ~1 t CH_4 $Month^{-1}$
- Emission rate:
  Summer: ~3 m^3 h^{-1} ; Winter: ~1.2 m^3 h^{-1}

MEMO

Methane emission modelling for non-gas tight digestate storage

Objectives:

- Cont. Long-term measurements of DS
- Parallel laboratory reactors
- Development of a model for emission prediction



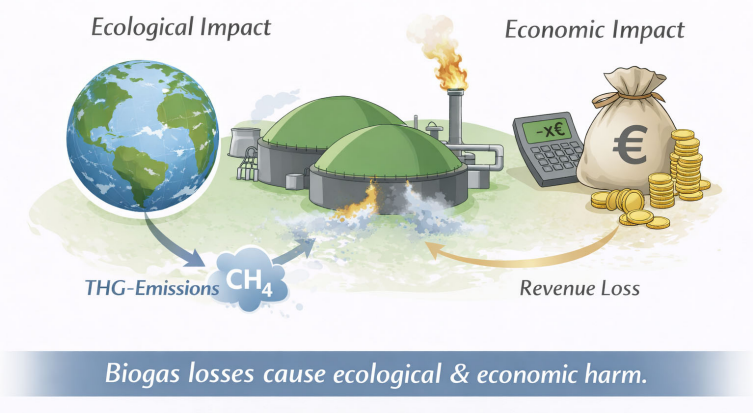
Results

- Monthly DS Temp. 14 – 24°C
- Methane Emissions: 0.3 t CH_4 $Month^{-1}$
- Methane emission rate: 0.62 m^3 h^{-1}
- Emission factor: 1.3% bis 4.4%

Example calculation of annual economic losses

Manure biogas plant according to an example of EEG-Monitoring		
Electrical Output	150	kW
Full-load operationg hours per year	8.760	h
Electrical efficiency approx.	39	%
Electrical energy yield for biogas	5	kWh_{el} per $m^3_{stp.}$
Realistic operationg hours per year	8.200	h

$$\frac{electrical\ Output\ [kW] * operating\ hours\ [\frac{h}{a}]}{electrical\ energy\ yield\ [\frac{kWh}{Nm^3 Biogas}]} = biogas\ production\ [\frac{Nm^3}{a}]$$



Biogas production	246.000	$m^3_{stp.}$ per year
Specific Cost per kWh Biogas	0,2765	€ per kWh_{el}
Assumption		
Assumed biogas losses	5	%
Biogas losses	12.300	$m^3_{stp.}$ per Year
Biogas losses	23.985	kWh_{el} per year
Economic losses	**6.632**	**€ per year**

Take away message

- **Methane emission mitigation is essential** due to its high global warming potential and its direct economic relevance as a loss of valuable product gas.
- **On-site approaches enable source-specific emission assessment** across individual process steps, allowing a differentiated evaluation and prioritization of emission sources within the plant.
- **Systematic leak detection and repair (LDAR) is crucial** for identifying unintended methane releases; many leaks originate from avoidable technical deficiencies (e.g., improperly closed valves) and can be mitigated with low effort.
- **Emission hotspots exist within biogas plants**, particularly at open digestate storage, combined heat and power (CHP) units, and biogas upgrading systems, requiring targeted monitoring and mitigation strategies.

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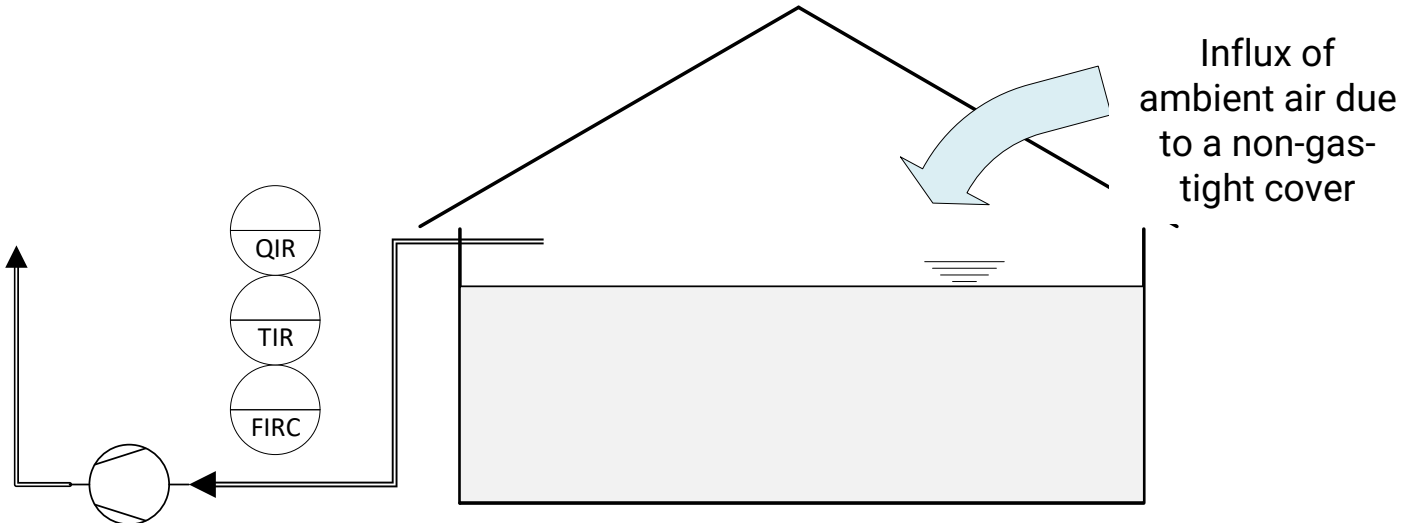
Smart Bioenergy – Innovations for a sustainable future

Contact:
Julian Matlach (M.Sc.)
julian.matlach@dbfz.de
+49(0)341/2434-380

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Torgauer Straße 116
D-04347 Leipzig
Phone: +49 (0)341 2434-112
E-Mail: info@dbfz.de
www.dbfz.de

Continuous emissions measurement

Project *MEMO:* continuously measurement (long-term monitoring) at non-gastight covered digestate storage



Measurement at a non-gas-tight covered digestate storage facility

Continuous gas extraction from the headspace beneath the cover, including measurement of gas flow rate and composition.

Monitoring of temperature and filling level in the digestate storage facility and the ambient temperature

Options to reduce methane emissions

Handling the methane slip

- Optimization of upgrading technology to reduce methane slip
- Combination of upgrading and subsequent methane oxidation in post treatment
- Combination of biomethane upgrading and CO_2 liquefication – if the liquefication exhaust is recycled back to the upgrading or utilized, the emissions are reduced

Handling the methane emissions from leaks

- Recurring leak detection tests with mobile FID or methane laser at gas-conducted elements (intern, monthly)
- Recommended: recurring leak detection tests from extern company (yearly)