Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

Emissions from biogas upgrading plants – results of the measurement campaign in Germany

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Workshop of IEA Bioenergy Task 37 - Energy from Biogas; 25.10.2023

EmMinA

Emission reduction during biogas upgrading, compression and injection

- **Duration:** Sep. 2021 – Aug. 2024
- **Lead:** DBFZ
- **Funding body:** Fachagentur Nachwachsende Rohstoffe e. V. (FNR)
- **Partner:** Rytec – Biogas und Bioenergieanlagen
- **Objectives:**

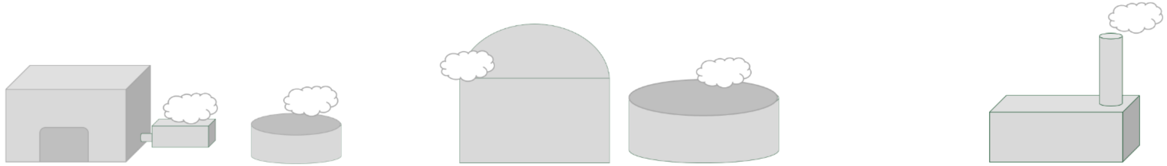
➢ Determination of emissions from biogas upgrading units and exhaust gas treatment (EGT) technologies

➢ Evaluation of EGT technologies in terms of cost, energetic efficiency, performance, emission reduction and operational experience.

➢ Evaluation of methane oxidation filters (MOX) for lean gas treatment as an alternative to existing processes for sites with low volume flows (Rytec).

Potential methane emission sources

GWP_{100} CH_4 → 28x stronger than CO_2



Substrate receiving & storage

- **Storage/mixing/hydrolysis**
  - Open/not-gastight tanks
  - Ventilation air (after bio-filter)
- **(Bio-waste) receiving/processing halls**
  - Ventilation air (after bio-filter)

Biogas production

- **Digestion/biogas storage**
  - Membrane diffusion through foil roofs
- **Digestate storage**
  - Open/not-gastight storage
  - Membrane diffusion through foil roofs
  - *Post-treatment*
- **OTNOC**
  - Leakages
  - *Activation of pressure relief valves*
  - *Digester openings*

Biogas utilization

- **CHP**
  - Off-gas/methane slip
- **Biogas upgrading**
  - Off-gas/methane slip
- **OTNOC**
  - Leakages
  - *Flaring*

OTNOC: other than normal operating conditions

Background

- End of 2022: 243 BGP with different BGUU in Germany
- Membrane separation currently most commonly used across the EU
- In Germany: Limitation of methane amounts in the separated CO_2/off-gas stream up to (0.2 %)

  → exhaust gas treatment required
- Exception: Amine scrubber
- Regenerative thermal oxidation (RTO) most commonly used process for exhaust gas treatment (EGT)

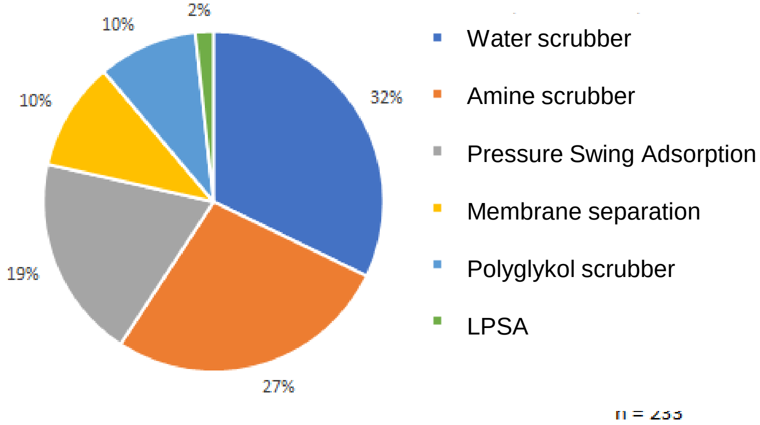


Figure: Distribution of biogas upgrading processes in Germany (DBFZ operator surveys, 2010 - 2022; data as of 04/2023)

Plant selection

No.	Process	EGT technologies	Initial operation	Feed-in capacity (m³/h biomethane)	Measurements
A01	Membrane sep.	RTO	2014	217	10/2022
A02	Membrane sep.	RTO	2016	727	11/2022
A03	PSA	RTO	2016	700	
A04	PSA	RTO	2013	406	05/2023
A05	Membrane sep.	RTO	2019	550	09/2023
A06	Amine based	-	2014	750	03/2023
A07	Amine based	-	2020	945	
A08	Amine based	-	2013	700	
A09	Membrane sep.	RTO	2017	350	
A10	Membrane sep.	RTO	2013	340	09/2023
A11	Membrane sep.	RTO	2015	620	04/2023
A12	Water scrubbing	RTO	2012	500	
A13	Water scrubbing	RTO	2013	1421	05/2023
A14	PSA	RTO	2013	500	
A15	Water scrubbing	RTO	remaining	remaining	

☆ Measurements completed
★ Measurements pending

Quelle: https://www.stepmap.de/landkarte/deutschlandkarte-0TbXIw8SPf-i

Measuring methodology

Single Source Analysis (on-site approach)

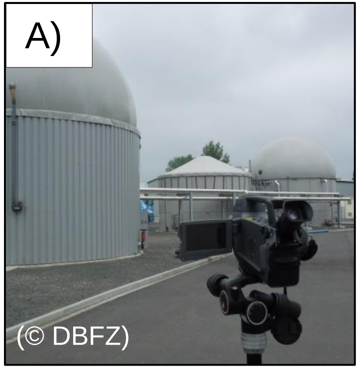
- Plant inspection → Identification of individual sources (OGI camera (A), methane laser).
- Setup of the measuring points depending on the source type
- Quantification:

A) Domes (volume flow + conc. measurement)

B) Q-OGI-camera

- Summation of the individual sources to the total methane load of the plant

OGI – Optical Gas Imagin



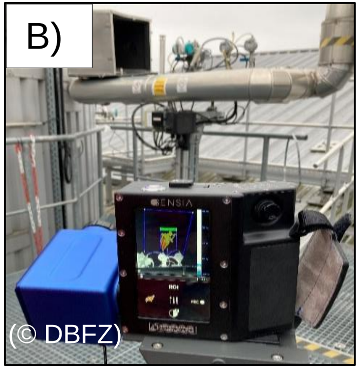
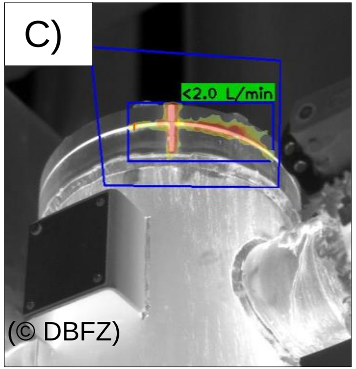


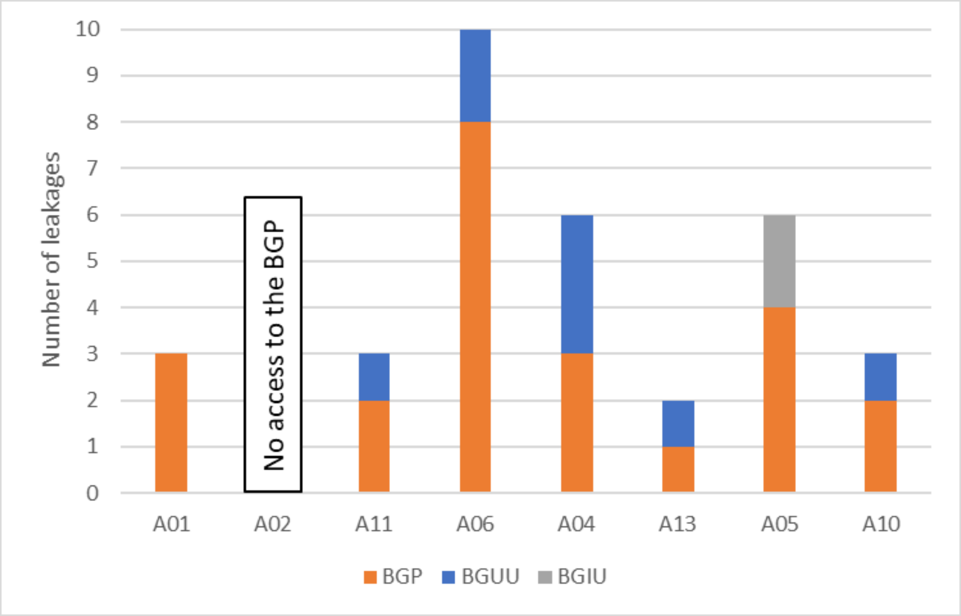
Abbildung:
A) OGI-camera (FLIR) in use for leak detection at the DBFZ research biogas plant;
B) Quantification by Q-OGI camera (SENSIA)
C) Quantification of a leakage on a flange



Typical emission sources at BGUU

- Gas-carrying plant components in the outdoor area
  (e.g. flanges, ball valves, valves, etc.)
- Enclosed plant components with forced ventilation
  (e.g. membrane- , compressor- or activated carbon containers)
- Exhaust gas of the BGUU after the RTO
- Feed-in station & Compressor station
  (e.g. leakages, overpressure blower, blower for gas analysis)

Leak detection



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

BGP: On average 3 leakages per plant

- Gas pipes, pipe penetration (8x)
- Wires to adjust agitators (6x)
- Increased CH_4 conc. in the supporting air (4x)
- Pressure relief valve (leakage) (1x)
- Pressure relief valve (operational emission) (1x)

BGUU: On average 1 leakages per plant

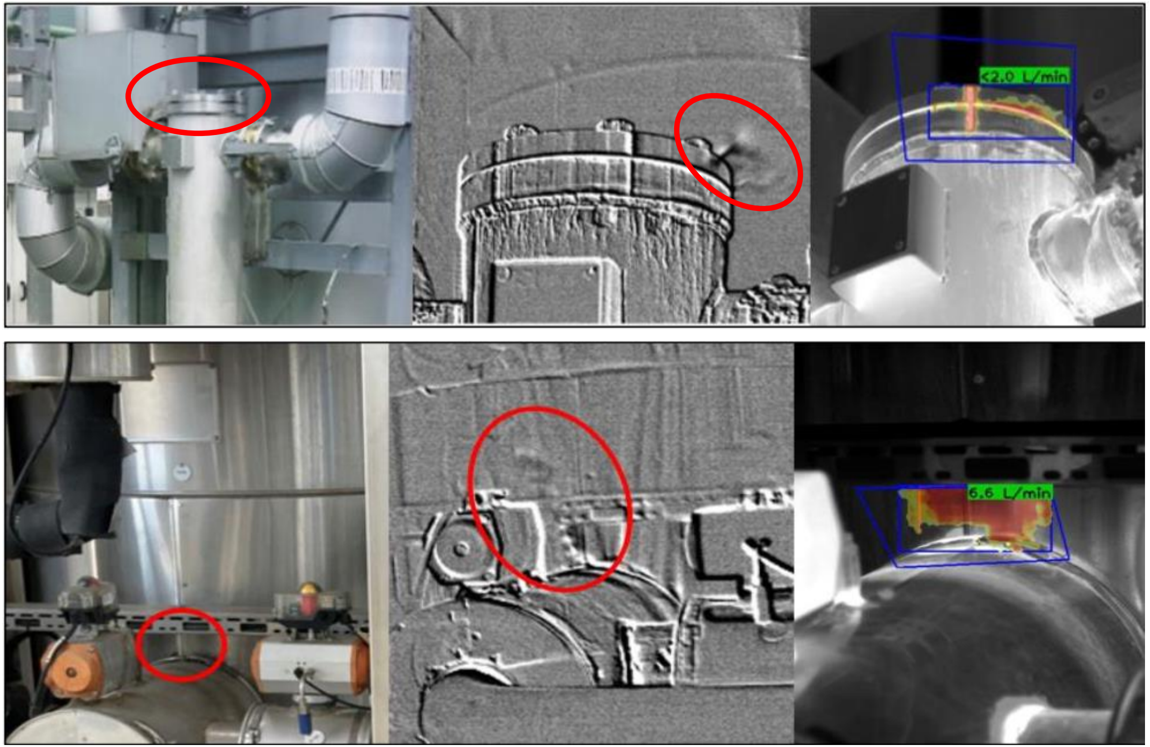
- Flanges, valves, ball valves

BGIU:

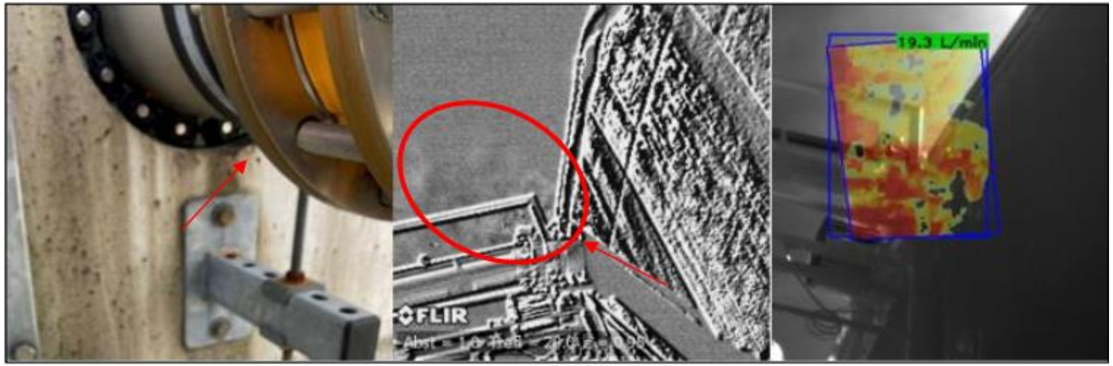
- At one plant increased methane leakage at overpressure blower

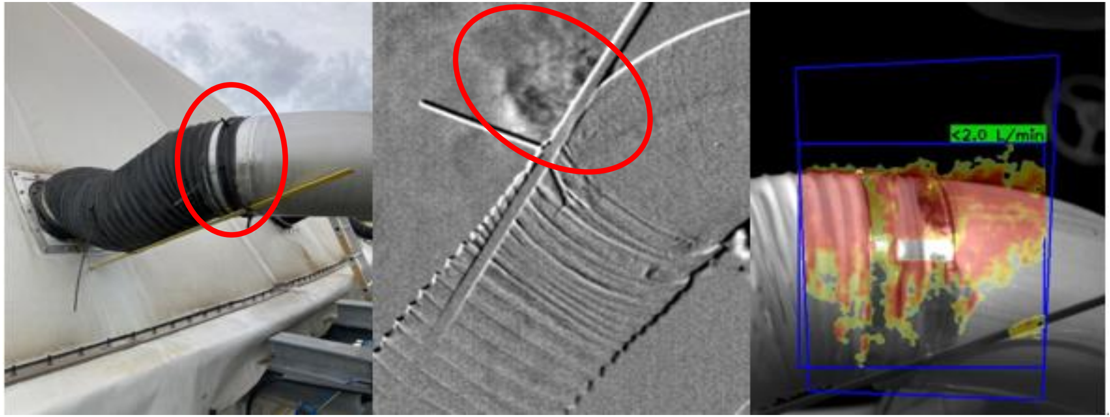
➢ On average 4 leakages were found per plant
➢ 1 out of 7 RTO units was not in operation

Biogas upgrading unit: Leakage from flanges and valves

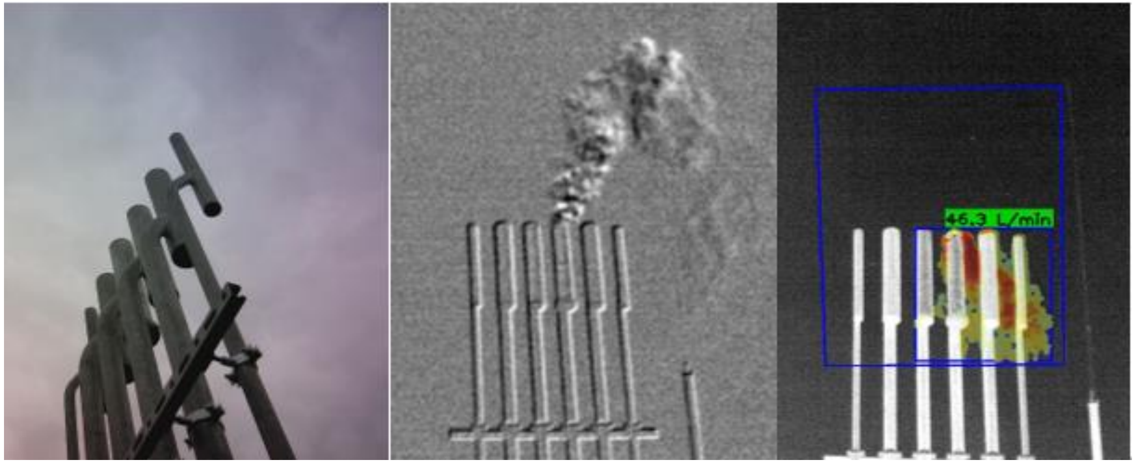


Leakage at a Gas pipes and pipe penetration to the fermenter/post digester

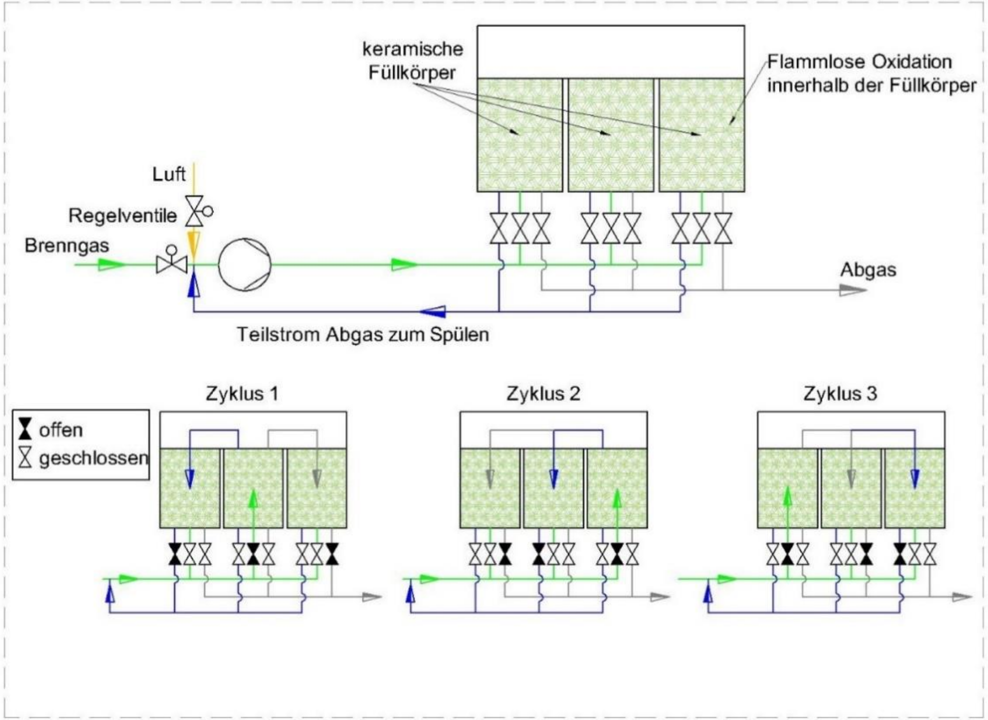




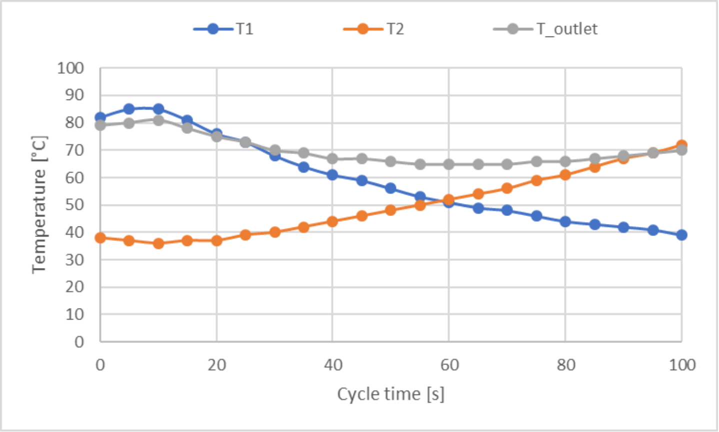
Compressor station of the feed-in unit (active blowout at overpressure)



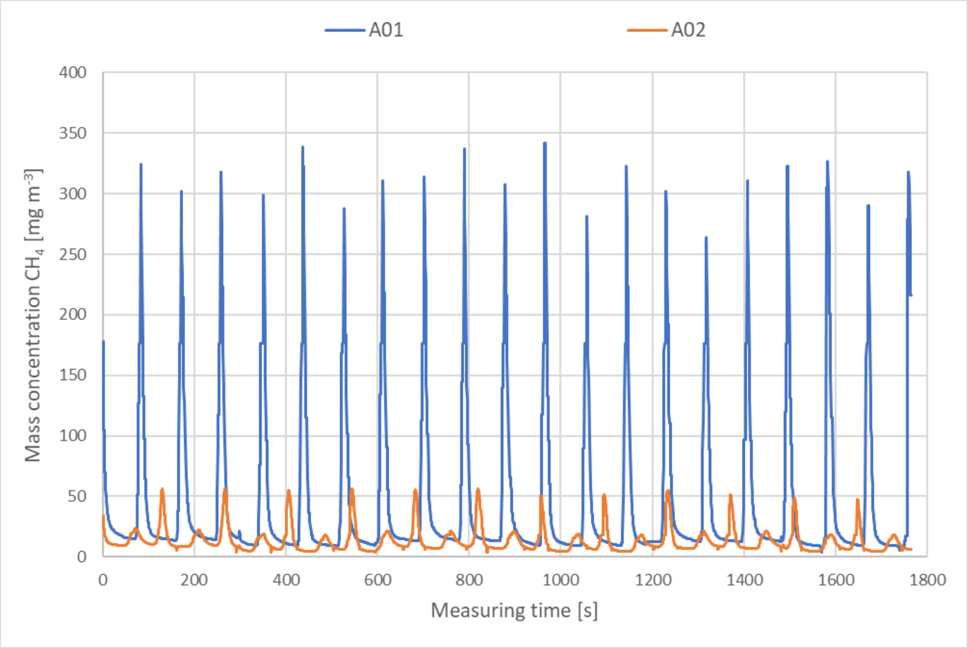
Regenerative thermal oxidation



- The gas to be treated flows into the heat exchanger, heats up and oxidizes.
- In the process, the inlet area cools down.
- Accordingly, there is still unburned gas in the cold inlet area when switching between cycles, which leads to emission peaks.



Emission peaks in the RTO exhaust gas



No.	Process	Max. peak [mg m⁻³]	Average [mg m⁻³]
A02	2-chamber RTO with backflush	57	13
A11	2-chamber RTO with backflush	46	13
A05	2-chamber RTO without backflush	271	26
A01	2-chamber RTO without backflush	342	46
A13	2-chamber RTO without backflush	826	219
A10	2-chamber RTO without backflush	2745	283
A06	without RTO	---	414
A04	RTO out of work	12796	6740

A01: 2-chamber RTO without backflush
A02: 2-chamber RTO with backflush

- Threshold of 20 mgC/m³ is only complied with by 2-chamber RTO with backflush

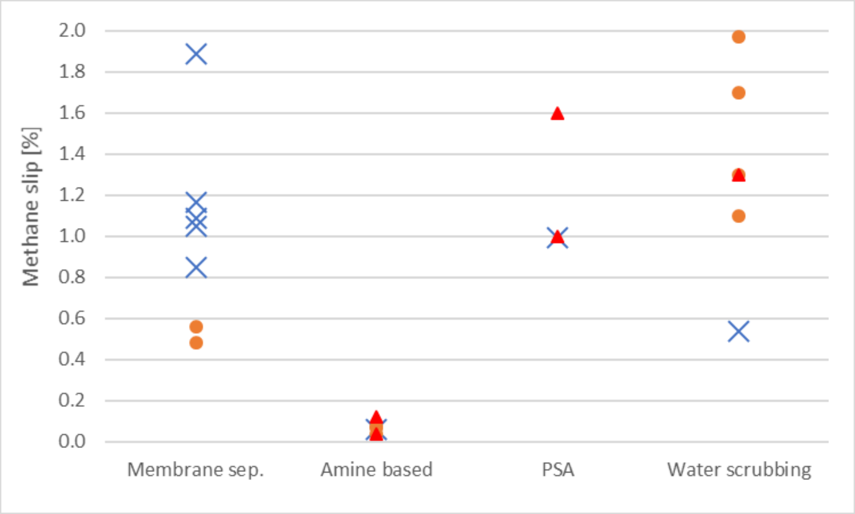
Exhaust gas measurements

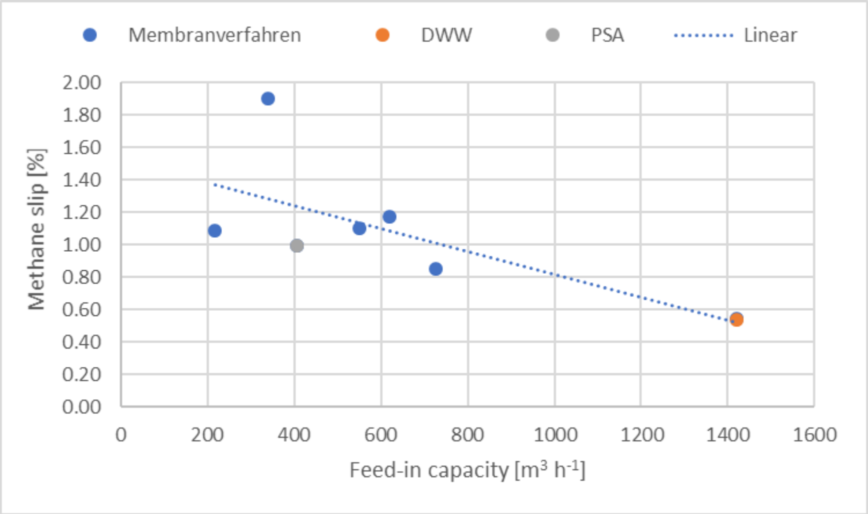
Nr.	Feed-in capacity	Initial operation	Process	CH_4 slip[1)]	EGT[2)]	Emission rate	EF-CH_4[3)]	Outlet temp. RTO
	[m^3 h^{-1}]	[Jahr]	[-]	[%]	[-]	[g_{CH4} h^{-1}]	[%]	[°C]
A01	320	2014	Membrane sep.	1,09	RTO	36	0.02	45
A02	730	2016	Membrane sep.	0,85	RTO	24	0.01	75
A11	700	2015	Membrane sep.	1,17	RTO	21	0.01	90
A06	750	2013	Amin based	0,06	-	276	0.05	-
A04	400	2013	PSA	0,99	RTO*	2504	0.86	k.A.
A13	1421	2013	Water scrubbing	0,54	RTO	561	0,06	110
A05	550	2019	Membrane sep.	1,1	RTO	30	0.01	70
A10	340	2013	Membrane sep.	1,89	RTO	666	0,27	200

1) before exhaust gas treatment EGT (operator information)
2) exhaust gas treatment (EGT)
3) Emission factor of the BGUU from the CO2 exhaust air flow related to the average biomethane production of the respective plant.
* RTO not in operation at the time of measurements due to maintenance work

- Average methane slip (without amine scrubbing) is 1.1 %
- Average EF-CH4 after the RTO (without A04) is 0.06%

Methane slip of different upgrading techniques



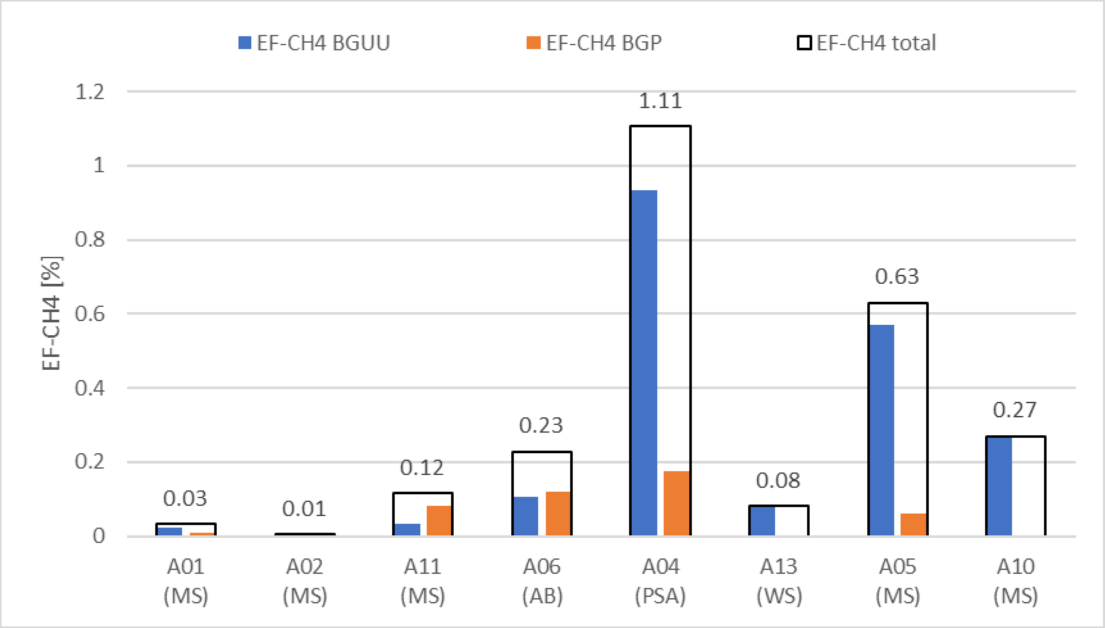


- EmMinA
- Kvist & Aryial, 2019
- MONA, 2015

Total emission factor of the plant A04

Plant area	Emission source	Q_{CH4} [g h^{-1}]	EF CH_4 [% CH_4]	Notes
BGUU	Exhaust gas	2504	0.862	Measurement at full load; RTO not in operation
BGUU	Leakage 1: CO_2 gas storage	60	0,021	
BGUU	Leakage 2: Flange	53	0,018	Has been fixed by the plant operator
BGUU	Leakage 3: Ball valve	91	0,031	
	Sum BGUU:	2708	0,932	
Fermentation	Supporting air	70	0,024	6 double membrane gas storage tanks with supporting air; determination of flow velocity at the supply air duct
Fermentation	Leakage 4: Foil roof connection	260	0,045	3 leaks found, 2 quantified with Q-OG camera
	Leakage 5: Pipe penetration	611	0,105	
	Sum Fermentation:	941	0,174	
Feed-in unit	Forced ventilation	0,003	0,000	
	Total amount:	**3649**	**1,11**	

Total emission factor per plant



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

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

- A02: no access to the BGP
- A04: RTO not in operation
- A05: 80% of emissions through overpressure blower at the Feed-in unit

➢ Average total EF-CH_4: 0,31 % (n=8)

Conclusion and outlook

- Mean methane slip of the measured BGUU (without amine scrubbing) is 1.1 % (n=7)
- The methane emission factor after the RTO was on average 0.06% (n=7)
- Average methane emission factor of the entire plant of 0.31% (n=8)
- On average 4 leakages were found per plant
- Emission measurements planned at 7 additional BGUU (in 2023 and 2024)
- RTO most widely used, technically the only solution for methane slip less than 2%.
- Heat extraction possibly a future solution

LEIPZIGER FACH-GESPRÄCHE

BIOGAS

Save-the-Date

Leipziger Biogas Fachgespräch
Emissions from Biogas Plants - Legal Framework, Measurement Methodology & Results from Field Measurements

29th of November 2023,
Leipzig / Online

Deutsches Biomasseforschungszentrum
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Smart Bioenergy – Innovations for a sustainable future

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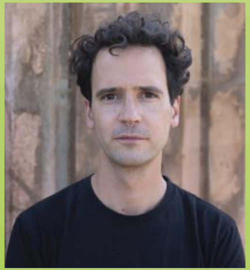

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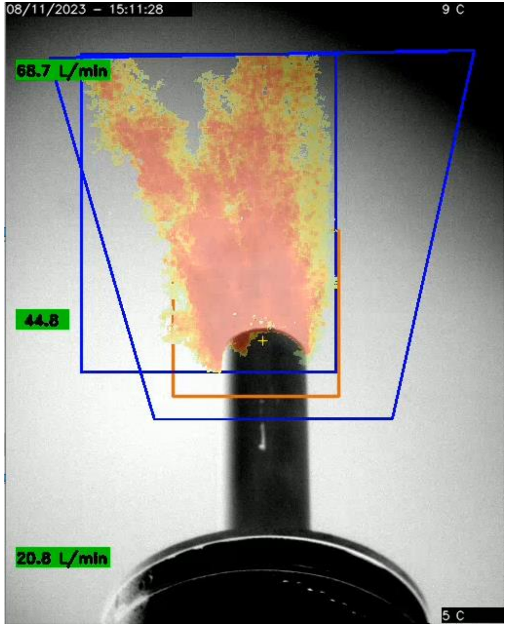
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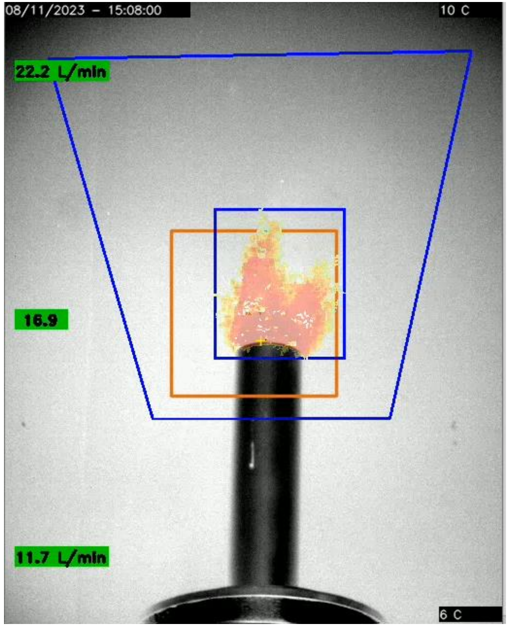
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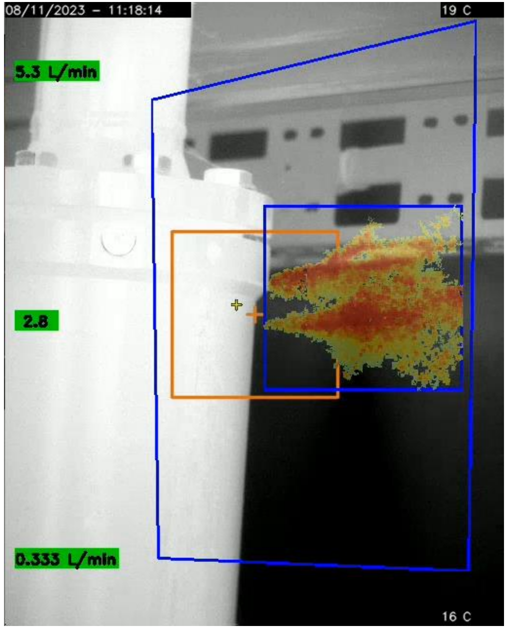
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