Monitoring and mitigating methane: Danish lessons for global action

27/06/2023
WEBINAR INFORMATION

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- **‘Chat’ box**: please use this for general requests and for interactive activities.

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*Please Note: Attendees’ microphones are muted. We cannot respond to ‘Raise Hand’.*
AGENDA

- Welcome and introductions
  
  *Amanda Lake (moderator)*

- Introduction to the Danish methane national monitoring programme
  
  *Charlotte Scheutz, Danish Technical University*

Q&A

- Legislation and rules implemented based on the national monitoring programme
  
  *Thomas Sørensen, Danish Water and Wastewater Association*

Q&A

- Case study – mitigating methane from PRVs
  
  *Anders Fredslund, DTU*

Q&A

- Case study – the methane journey at VCS Denmark
  
  *Per Henrik Nielsen, VCS Denmark*

- Q&A Discussion

- Final remarks and conclusion
MODERATORS & PANELISTS

Amanda Lake
Jacobs, United Kingdom

Charlotte Scheutz
Danish Technical University
Denmark

Thomas Sørensen
DANVA
Denmark

Anders Fredeslund
Danish Technical University
Denmark

Per Henrik Nielsen
VandCenter Syd
Denmark
Introduction to the Danish methane national monitoring programme

ANDERS FREDENSLUND & CHARLOTTE SCHEUTZ, DTU, DENMARK
SHARE OF BIOMETHANE IN THE DANISH GAS SYSTEM

~ 40%
METHANE LOSS AND CLIMATE IMPACT

Scenario A: Biogas upgrade

- 1% CH₄ loss
- 2% CH₄ loss
- 5% CH₄ loss
- 10% CH₄ loss
- 20% CH₄ loss

GHG emission (tonne CO₂-eq yr⁻¹)

Fossil fuel substitution
Chemical fertiliser substitution
Transport of feedstock and digestate
Change in manure management
Electricity and heat use
Direct CH₄ emission

Scheutz & Fredenslund, 2019. Total methane emission rates and losses from 23 biogas plants. Waste Manage. 97, 38-46
PROJECT OBJECTIVE

Biogas plants:
- Assistance in self-control monitoring program
- Assistance in leak finding
- Quantification of methane loss from the plant
- Assistance in minimizing leaks/methane loss

Industry and government:
- Improved knowledge in the field
- Reduction of the total methane loss from biogas to 1%
- Revision of national emission factors for Danish biogas
PROJECT CONTENT

- **Task 1: Build and disseminate knowledge to reduce methane loss**
  - Development of self control programs for biogas facilities and determination of BAT
  - Guidance materials for the biogas industry to reduce methane loss
  - Facilitate experience between biogas producers on reduction options
  - Feasibility studies, individual plants

- **Task 2: Measurement program**
  - Development, QA, best practice regarding measurements of methane emission
  - Leak search on biogas plants
  - Quantification of methane emissions (total emission and selected point sources)
  - Establishment of a national database on emissions for national GHG reporting
  - Contribute with suggestions regarding regulation / conditions for subsidies in the future
PARTICIPATING BIOGAS PLANTS

- 60 biogas plants – 35 agricultural plants and 25 wastewater treatment (WWTP) and industrial plants
- 45% of the Danish biogas production
- Previous measurements from additional nine plants included in calculating emission factors
- Variety of plants:
  - Type of plant (agricultural, WWTP)
  - Size (magnitude of gas production)
  - Gas utilization (CHP, biomethane, off-site utilization)
  - Construction year
METHANE LEAK SEARCH
The method is:
• Well-documented (control test and international comparison tests)
• Certified
• Applied at many different sources
IDENTIFIED METHANE LEAKAGES

Most common leaks

- Pressure relief valves on digesters
- Biomass storage w/o gas collection (especially WWTP)
- Leakages at gas bearing components (gas storage, piping, inspection hatches and more)

WHOLE PLANT METHANE EMISSIONS (KG CH$_4$/H)

PLANT METHANE LOSS (% OF METHANE PRODUCTION)


<table>
<thead>
<tr>
<th>Plant type</th>
<th>Number of plants</th>
<th>Methane loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural plants</td>
<td>44</td>
<td>4.7</td>
</tr>
<tr>
<td>Wastewater treatment plants</td>
<td>25</td>
<td>11.3</td>
</tr>
<tr>
<td>All types</td>
<td>69</td>
<td>8.0</td>
</tr>
</tbody>
</table>
METHANE EMISSION FACTOR (%), WEIGHT-BASED PRODUCTION

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Number of plants</th>
<th>Emission factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural plants</td>
<td>44</td>
<td>2.1</td>
</tr>
<tr>
<td>Wastewater treatment plants</td>
<td>25</td>
<td>6.7</td>
</tr>
<tr>
<td>All types</td>
<td>69</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Current EFs are 1.3% for WWTPs and 4.2% for agricultural

METHANE EMISSION DYNAMICS AT A WWTP

CONCLUSIONS

- High variation in methane emissions (kg CH$_4$/h) and methane loss (% of production) between biogas plants
- Smaller plants had higher losses than bigger and more recently built plants
- WWTPs had higher methane losses than agricultural plants
- Important contributors to methane emission from biogas production:
  - Pressure relief valves on digesters
  - Biomass storage w/o gas collection (especially WWTP)
  - Leakages at gas bearing components (gas storage, piping, inspection hatches and more)
- Methane losses were higher than expected
- It is technically possible to operate a plant with a loss less than 1% (national target set by Danish biogas producers)
- More insight into methane emission dynamic is needed
CONTACT INFORMATION

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What to know more


Link to the report on methane losses from Danish biogas plants:
https://ens.dk/presse/ny-rapport-om-metantab-fra-danske-biogasanlaeg
MODERATOR: AMANDA LAKE
LEGISLATION AND RULES IMPLEMENTED BASED ON THE NATIONAL MONITORING PROGRAMME

THOMAS SØRENSEN, DANISH WATER AND WASTEWATER ASSOCIATION (DANVA)
Danish Watersector

Inhabitants in Denmark: ~ 5.8 million

**Drinking water:**
- Number of waterworks: 2,400
- Annual extraction ~ 370 million
- 100% groundwater, simply treated, no chlorine added

**Wastewater:**
- 102 Companies
- 643 WWTP above 30 PE
- Annual treatment of Wastewater: 7,800,000,000 m³
- Biogasplants situated at WWTP: ~ 50
- Total annual turnover water services: 2.3 billion euro
- 100% public owned
- Financed exclusively through tariffs

See page 10-11 in www.danva.dk/waterinfigures
STORYLINE FOR METHANE REGULATION

2020: The Danish government has set a target of a 70% reduction in CO2 in 2030, based on the state's national climate accounts.

2021: The Danish Minister of the Environment set a goal of energy and climate neutrality in 2030 for the Danish water sector. The biggest scope 1 emission is nitrous oxide, followed by methane.

2021: New methane report on biogas plants: Average emission: 7.7% based on 25 WWTP.
   National CO2 accounting: Emission from biogas plants set to 1.3% of production.

2021: COP 26 Glasgow: Agreement om methane reduction by 30% signed by the Danish Minister of energy.

2022: Climate agreement on green electricity and heat 2022: “Denmark Can Do More II”:
   – The government will advance and increase biogas production.
   – A regulation of methane loss from biogas production is introduced, which limits methane loss as much as possible.

2023: On January 1. new rules for methane loss from biogas plants were implemented
LEGISLATION AND RULES


- Requirements for a self-monitoring program
- An annual review and leak detection of all biogas plants in Denmark
  - There is a requirement for the rectification of errors/leaks that are listed in the report.

And maybe later:

- The emission from gas engine and methane upgrading plants: max. 1 %

The goal is to manage the operation and maintenance of facilities and thereby not to have a specific measurement from each plant.

The goal is an emission of 1 % of production from the biogas plants in Denmark.
The requirements only apply to WWTP with biogas production and not to WWTP without biogas. All units connected to the biogas plant are included by the regulation. All other processes at the WWTP are excepted.
REQUIREMENTS FOR A SELF-MONITORING PROGRAM:

Purpose:
Minimizing methane loss by
Weekly, monthly and annual self-monitoring program.

A template has been prepared to help the
Biogas plant who did not already have an adequate self-monitoring program.

The program must be prepared in collaboration with an external company

Focus points:
- Coverings
- Pipe penetrations
- Valves
- Fittings

Methods:
- Gas sniffer
- Gas chamber
- Visual and auditory control
- Soapy water
- Closeness
AN ANNUAL REVIEW AND LEAK DETECTION PROGRAM

The annual review should be carried out by an external independent company.
The companies shall be pre-approved by the Danish Energy Agency.

- There is a list of approved companies at the Agency’s website. (7 companies)

The Agency has published a template for reporting and a guidance on how the review should be carried out.

The review results in a report on methane emissions and requirements for improvement.

The report shall be sent to the WWTP and to the Danish Energy Agency.

The review must be carried out every year - however with the possibility of a reduced frequency if the WWTP are doing well.
AN ANNUAL REVIEW AND LEAK DETECTION PROGRAM

An annual review and leak detection program of all biogas plants by an external company:

- Leak detection on all gas-carrying components
  - Valves, pipes, covers, fittings
- Identifying any other sources of methane loss
  - Open sludge storage is probably the biggest problem on WWTP

The report must contain:

- That the self-control program has been reviewed and checked
- Findings below the “signifikant - limit” added to the self-monitoring program.
- Findings above the “signifikant - limit and recommendations for rectifying these.
- Other sources and recommendation for improving these.

- The WWTP is obliged to implement the listed leakage/findings/errors.
EMISSION FROM GAS ENGINE AND UPGRADING PLANTS

In the initial legislative work, there was a desire to set requirements for the emissions from the gas engine and methane upgrading plants to maximum 1 % of the gas production.

Problems:

- The goal was very ambitious because it is almost impossible to have a gas engine with emission below 1 % - applies to both for new or newly refurbished engines.

- Two different agencies will set different requirements for the same emission from the same gas engine:
  - The Danish Energy Agency will set requirement for methane (new requirement)
  - The Danish Environmental Agency already have requirement for Nox (existing requirements)

The 2 agencies have to discuss in more details how a claim can be made. Requirement will be introduced later.

From 1. January 2024 a requirement is introduced for upgrading plants on maksimum 1 % emission.

Only one or two WWTP have upgrading plants for biogas.
SUMMARY: LEGISLATION AND RULES

- The new regulation is based on the concept that a maintained plant and on-going review of the facilities will ensure as little methane leakage as possible.

- It is chosen not to make a requirement for measuring “The total methane emission from the plant”.

- Point sources:
  - Upgrading plants: < 1%, Gas engine: Demands are coming later
  - Open sludge storage: Perhaps a requirement for cover

The Danish Energy Agency has a website with the related material as “Guideline for review and leak detection”, “Template for reporting the review” and “Template for self-monitoring program”. And the list of pre-approved external independent companies. Link (only in Danish)
QUESTIONS?

Thomas Sørensen
Manager of data and Benchmarking
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Water in figures
(always latest version):
www.danva.dk/waterinfigures
Q&A

MODERATOR: AMANDA LAKE
Case study – mitigating methane from PRVs

ANDERS FREDENSLUND & CHARLOTTE SCHEUTZ, DTU, DENMARK
AGENDA

1. What are pressure relief valves (PRVs), and why are they a focus point?
2. Methods and results regarding PRVs – Danish national effort to minimise CH$_4$ emissions from biogas plants
3. Observed emission rates from installed PRVs
4. Tested leakage from new valves
5. Conclusions
6. Additional information
WHAT ARE PRVS, AND WHY ARE THEY A FOCUS POINT?

- PRVs (or “breather valves”) ensure a set, maximum pressure difference between a tank and the atmosphere to prevent rupture or implosion.
- Ensures that air can flow in or out, when liquid levels are changed, or relieve pressure, in case of excess gas production.
- Two types of gaseous emission: (1) functional and (2) leakage.
- An often-observed cause of leakage from top of biogas reactors.
- Leakage of CH$_4$ contributes to climate change, and reduces energy production (and thus revenue).
NATIONAL EFFORT – PRV RELATED RESULTS

- Leak search was done at 50 biogas plants using gas cameras (FLIR GF320) and “sniffers” in combination.
- Leakage from PRVS was observed at 53% of facilities (89 times observed).
- Rates of leakage were not quantified.

<table>
<thead>
<tr>
<th>Location of observed leak/point source of emission</th>
<th>Times observed</th>
<th>Frequency of observation among plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure relief valves</td>
<td>89</td>
<td>53 %</td>
</tr>
<tr>
<td>Reactors – other leaks</td>
<td>100</td>
<td>59 %</td>
</tr>
<tr>
<td>Biomass storage tanks</td>
<td>129</td>
<td>67 %</td>
</tr>
<tr>
<td>Gas storage units</td>
<td>7</td>
<td>12 %</td>
</tr>
<tr>
<td>Other gas bearing components</td>
<td>137</td>
<td>65 %</td>
</tr>
</tbody>
</table>
METHANE LOSS BEFORE AND AFTER MITIGATING ACTIONS

- At six plants, methane emission was measured both before and after GHG mitigation actions
- Loss before: 3.7%, loss after: 2.1%
- Avoided GHG: 29,400 ton CO$_2$ eq./yr.
- Avoided loss of CH$_4$: 1.5 million Nm$^3$/yr. (≥ production increase)
- At all six plants, PRVs were replaced, but other mitigation actions were also taken

OBSERVED EMISSION RATES FROM INSTALLED PRVS

- DBFZ study by Torsten Reinelt & Jan Liebetrau: 2-years, continuous measurement of leakage from PRVs
- Emission rate measured using flowmeter on PRV’s exhaust combined with measured gas composition
- Emission factor varied – up to 10% loss in connection to maintenance works, and affected by fast temperature change
- Overall emission factors: 1.8% and 0.6% for the first and second years, respectively
- Emissions lowered after mitigation effort

Source: Reinelt, T., Liebetrau, J. (2020). Monitoring and mitigation of methane emissions from pressure relief valves of a biogas plant. Chemical Engineering & Technology, 43, 1, 7-18
TESTED LEAKAGE FROM NEW VALVES

- Test results provided by Ewart Cox, Assentech
- Two new PRVs were tested for leakage: “good PRV” and “bad PRV”…
- Leakage measured at 90% of SP
- Leakage from “good PRV”: 4.9 M$^3$/yr.
- Leakage from “bad PRV”: 1700 M$^3$/yr.

Example of financials provided:
“The cost of the cheap valve was £3000. That was a 12 inch size unit in carbon steel from a British manufacturer. The replacement valve cost £6500 from a high quality international manufacturer. The saving from one valve position was over £8000 in 1 year so payback was approximately 10 months.” (Ewart Cox)
CONCLUSIONS

- Leakage from PRVs is an often observed source of CH$_4$ emission from biogas production
- Emission can be both a result of the PRVs function and from leakage
- Rate of leakage varies highly between valves, where “good PRVs” can have near 0 leakage
- Leakage from PRVs can cause significant loss of revenue and greenhouse gas emission
ADDITIONAL INFORMATION

Research paper:


Research paper:


Emission calculator + services:


Contact:

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Charlotte Scheutz: chas@dtu.dk
Q&A

MODERATOR: AMANDA LAKE
Case study – the methane journey
VCS Denmark

PER HENRIK NIELSEN VCS DENAMRK

inspiring change
- Established 1853
- Odense – 3rd largest city in Denmark
- 6 WTPs ~180,000 customers
- 8 WWTPs ~235,000 customers
- Energy neutral utility since 2019
- Committed to innovation
**Wastewater**

- 115 km² catchment area
- 2,200 km of sewers
- 390 storm water overflows
- 300 pumping stations, main sewers
- 23,000 tons sludge production (24% DM)
- 8 biological treatment plants
- 36 mill. m³ treated per year
- 582,200 treatment plant capacity, PE
ENERGY BALANCE

MWh


Total energy consumption (Elec., Heat, Trucks & Cars)
Own energy production
Net energy consumption
ENERGY MIX

Change in carbon intensity of electricity, 2000 to 2022
Carbon intensity is measured in grams of carbon dioxide-equivalents emitted per kilowatt-hour of electricity.

Source: Ember Climate (from various sources including the European Environment Agency and EIA)
OurWorldInData.org/energy • CC BY
<table>
<thead>
<tr>
<th>Scope 1</th>
<th>Scope 2</th>
<th>Scope 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.314 ton CO₂</td>
<td>2.359 ton CO₂</td>
<td>24.930 ton CO₂</td>
</tr>
</tbody>
</table>

**Outside scope**

**Udenfor scope**

Total 36.306 ton

7.551 ton CO₂

- Biogenic CO₂ from biogas
- Energy production from biogas
- Afforestation
ARES

- Project goal - Reduced emissions from wastewater treatment

- Methane CH4 and Nitrous oxide N2O – are the main problems

- A co-operation between leading utilities, universities, consultant and partly funded by the EPA

- The project includes:
  - New advanced sludge handling
  - Advanced measurements at treatment plants
  - Advanced measurements in sewer systems
  - Pilot plant testing of new and enhanced control strategies
  - Online measurement – new approach
REDUCTION OF EMISSION FROM SLUDGE STORAGE

Development and test of closed sludge storage tank including vacuum technology for maximized methane extraction

- New closed sludge storage.
- Maximizing gas production from the plant
VACUUM ENHANCED SYSTEM - ELIQUO

- Inclusion of vacuum technology to remove dissolved methane from the sludge
- Possible addition of magnesium or iron to enhance controlled phosphorus precipitation
FINDING THE EMISSIONS

- Identification and quantification of emissions of methane and N2O from WWTP using trace gas method

- Measurement of methane and N2O from the sewer system in Odense using trace gas method
CONCLUSION

- The project will put focus on emissions from our industry
- Minimizing a well-known source of methane emissions
- Give new insights on overall emissions from treatment plants and sewer systems
- Test of new control strategies and low emission operation
- New approach for measuring N2O emissions
- Evaluate validity of Denmark's IPCC reporting
A GREAT TEAM
The case of VCS Denmark – progress beyond net energy production - The Source (thesourcemagazine.org)
Q&A DISCUSSIONS

MODERATOR: AMANDA LAKE
WHAT NEXT: 2 FURTHER WEBINARS

Monitoring and mitigating nitrous oxide: Danish lessons for global action- Anna Katrine, Envidan
- 04 September

Climate Smart Water Futures within Planetary Boundaries- IWA GHG working group
- 03 October
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Alexandru (Ali) Gagnea, HRSD - USA
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Victoria Ruano, Valencia University - Spain
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