WORLD BIOGAS ASSOCIATION

Biogas Masterclass with Danish Experts: *Sustainability and methane leakage*

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Enabling the introduction of Danish biogas and waste solutions into the North American market.

Biogas Go Global

Food & Bio Cluster Denmark

ROYAL DANISH EMBASSY
The Trade Council

Danish Biogas Alliance North America

- Enzyme blends to break down organic feedstock more quickly
- Engineering specialized in biogas and nutrient recovery
- Separation of food waste organics from inorganics = 99.9 % pure biopulp
- Peristaltic pumps for digester and food production applications
- Amine scrubbing for ad/de-sorption of CO2
- Superior solutions for AD systems (finance, build, own, operate)
- Biological desulfurization of biogas with no use of chemicals

THE WASTE , RECYCLING & BIOGAS ADVISORY PROUDLY PRESENTS

BIOGAS ALLIANCE 2022

novozymes

GEMIDAN ECOGI

Qenew energy

ISN • PUMPS USA Inc.

Ammongas

nature energy

BIO GASCLEAN

Biogas Go Global

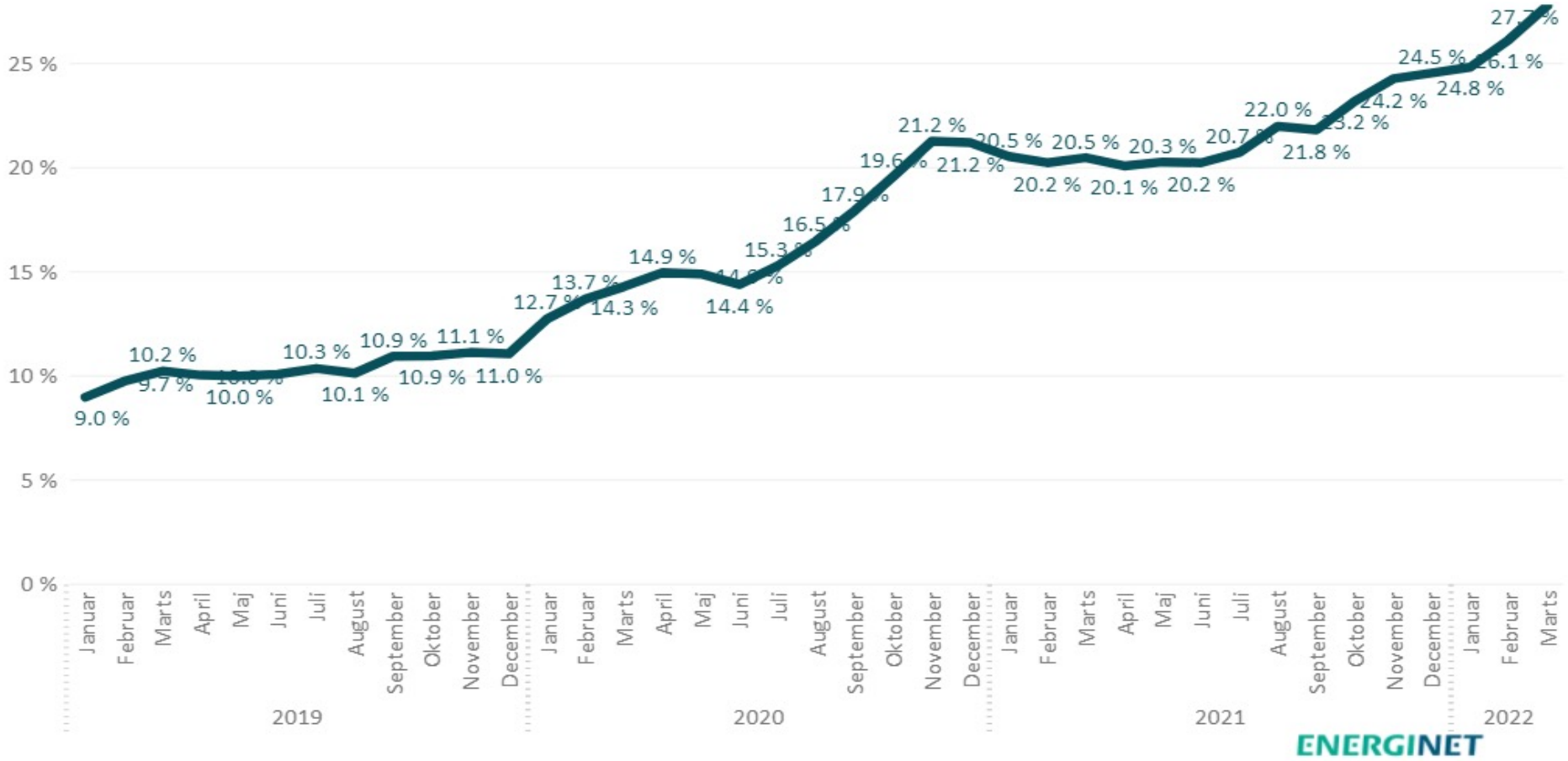
- Biogas Go Global provides a commercial, R&D and policy knowledge sharing platform for the accelerated growth of the biogas industry in the United States, Denmark and other partner countries by establishing collaboration between industry, academia and the private sector.
- The goal of Biogas Go Global is to grow the global biogas sector through partnerships between Danish and partner country stakeholders.
- www.biogasgoglobal.com

WASTE, RECYCLING AND BIOGAS ADVISORY

Food & Bio Cluster Denmark

Danish Energy Agency

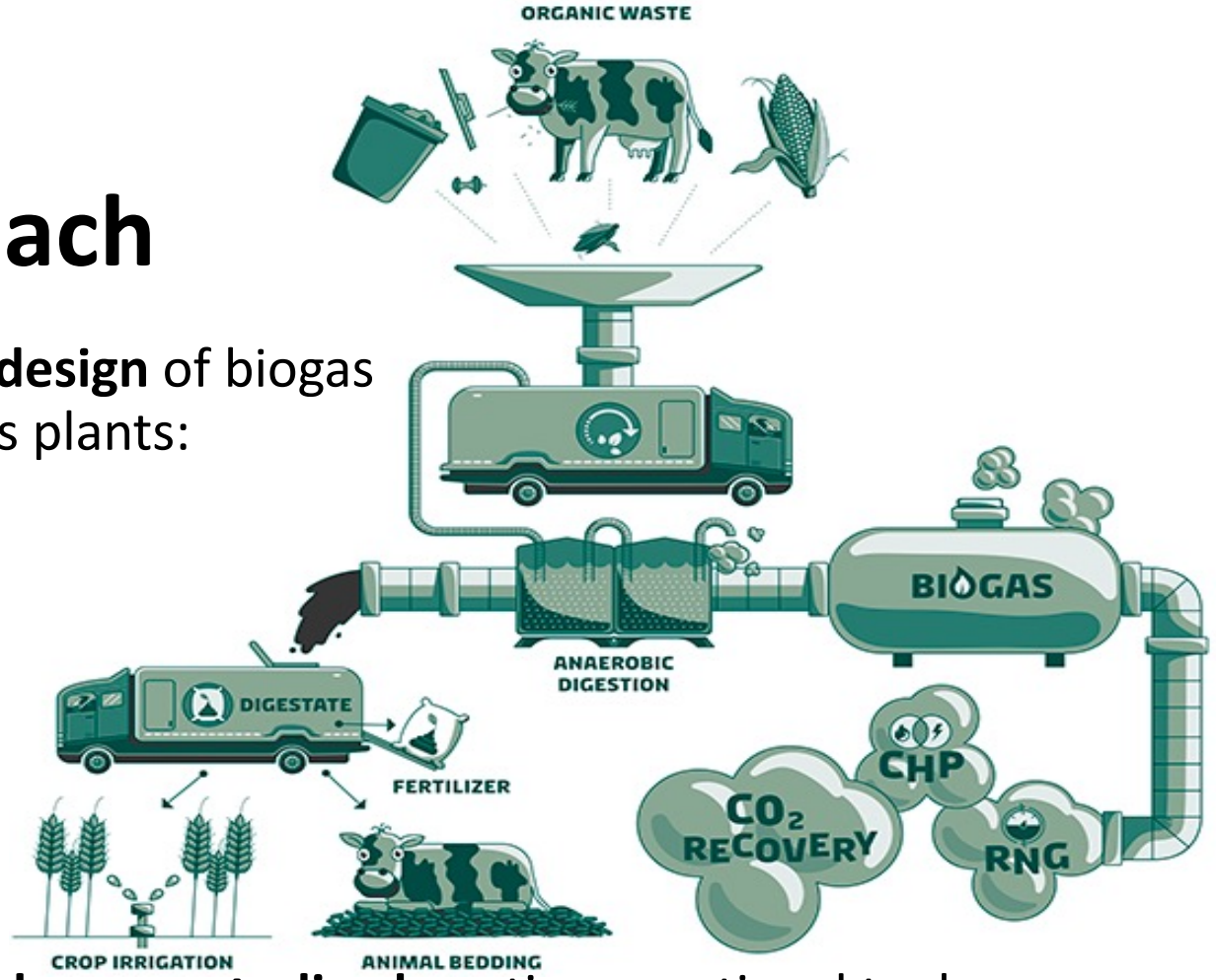
Share of RNG in the Danish gas system



Denmark is the country in the world with the highest share of biomethane in the gas grid!

The Danish Biogas Approach

- The Danish biogas sector has **specialized in the design** of biogas plants and **production of components** for biogas plants:
  - Biomass pre-treatment solutions
  - Digester tanks
  - Mixer for the digester tanks
  - Upgrading equipment



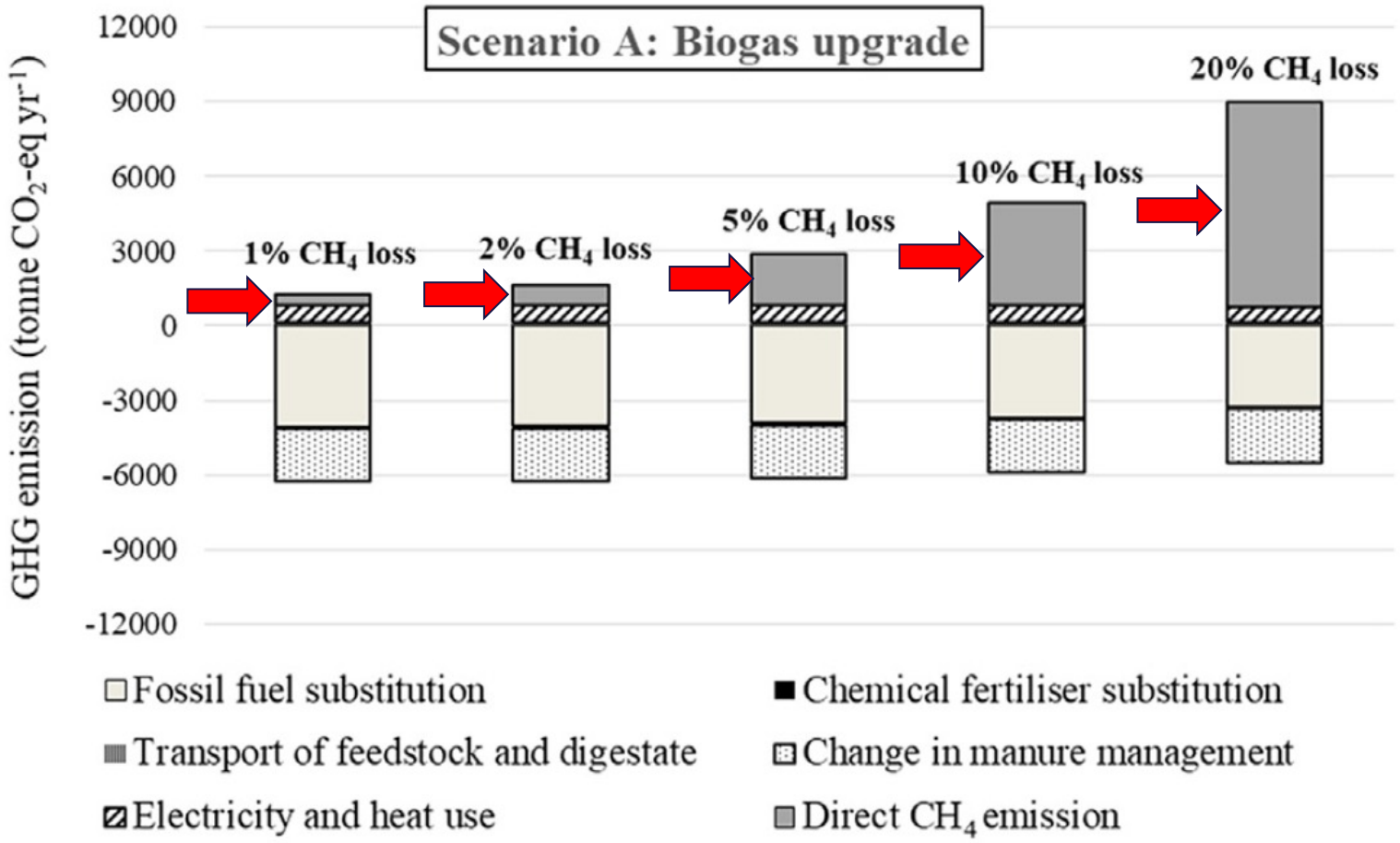
- Most of the biogas production in DK is based on **large centralized** continuous stirred tank reactor plants with **co-digestion** and own **upgrading** facilities with direct injection of the RNG into the natural gas grid

Sustainability and methane leakage | 21st April 2022

Charlotte Scheutz, Einar Gudmundsson & Anders M. Fredenslund

Methane emissions from biogas production plants

Methane loss and GHG performance



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

Project content – ”Metantab fra danske biogasanlæg”

- **Task 1: Build and disseminate knowledge to reduce methane loss**
  - Development of self control programs for biogas facilities and determine 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 emission (total emission and selected point sources)
  - Establish a national database on emissions for use in the national reporting of GHG emissions

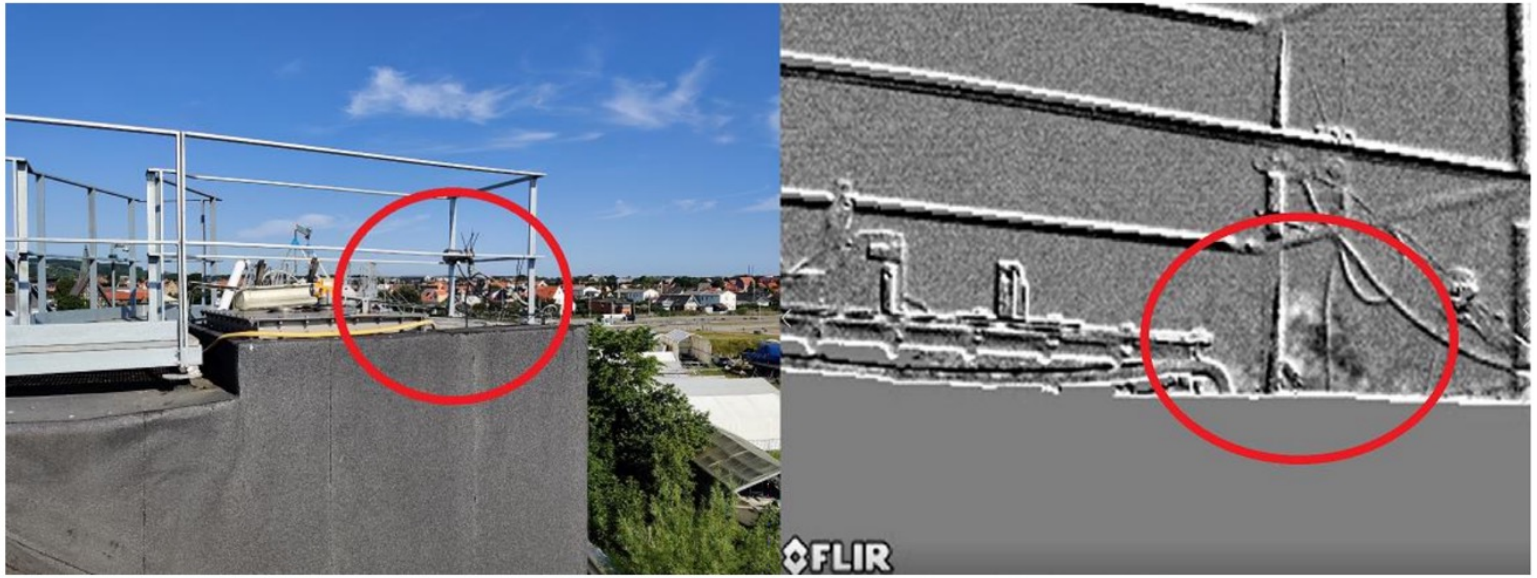
RAMBØLL Bright ideas. Sustainable change. DTU Miljø Institut for Vand og Miljøteknologi FORCE TECHNOLOGY TEKNOLOGISK INSTITUT Energistyrelsen

Participating biogas plants

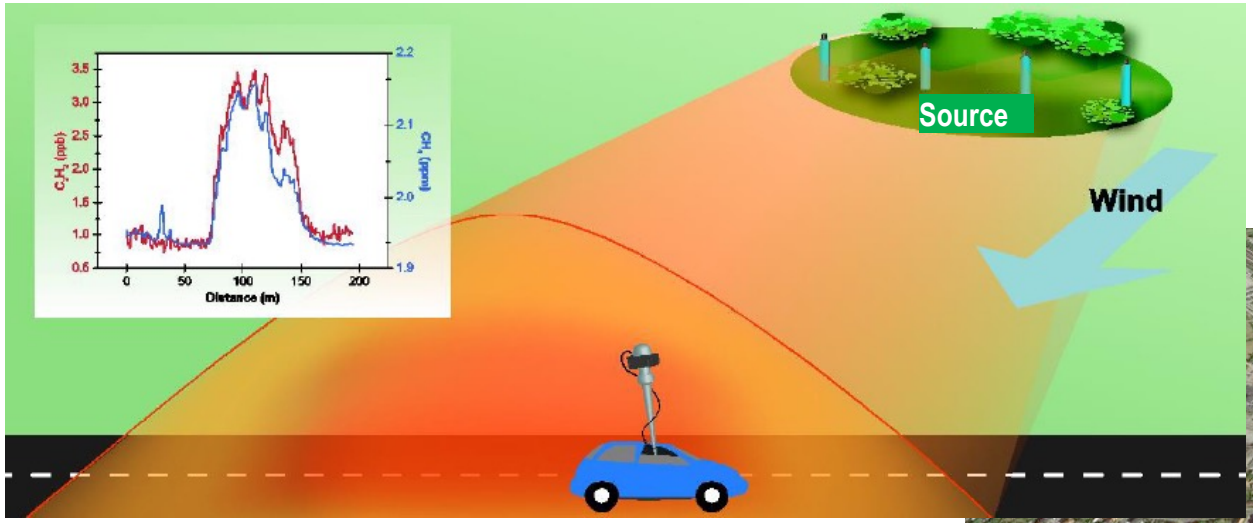
- 60 biogas plants – 35 agricultural plants and 25 wastewater treatment (WWTP) and industrial plants
- 45% of the Danish biogas production
- Previous measurements from additional nine plants included in calculating emission factors
- Variety of plants:
  - Type of plant (agricultural, WWTP)
  - Size (magnitude of gas production)
  - Gas utilization (CHP, biomethane, off-site utilization)
  - Construction year

Methane leak search

Leak search using gas camera



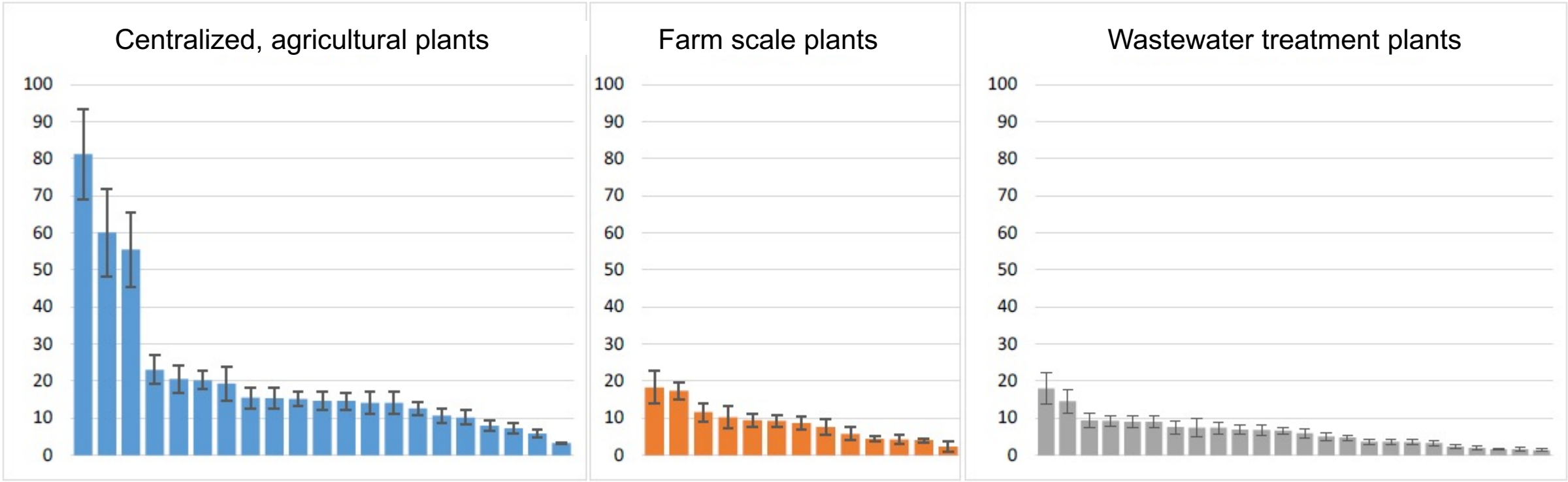
Quantification of whole site methane emission



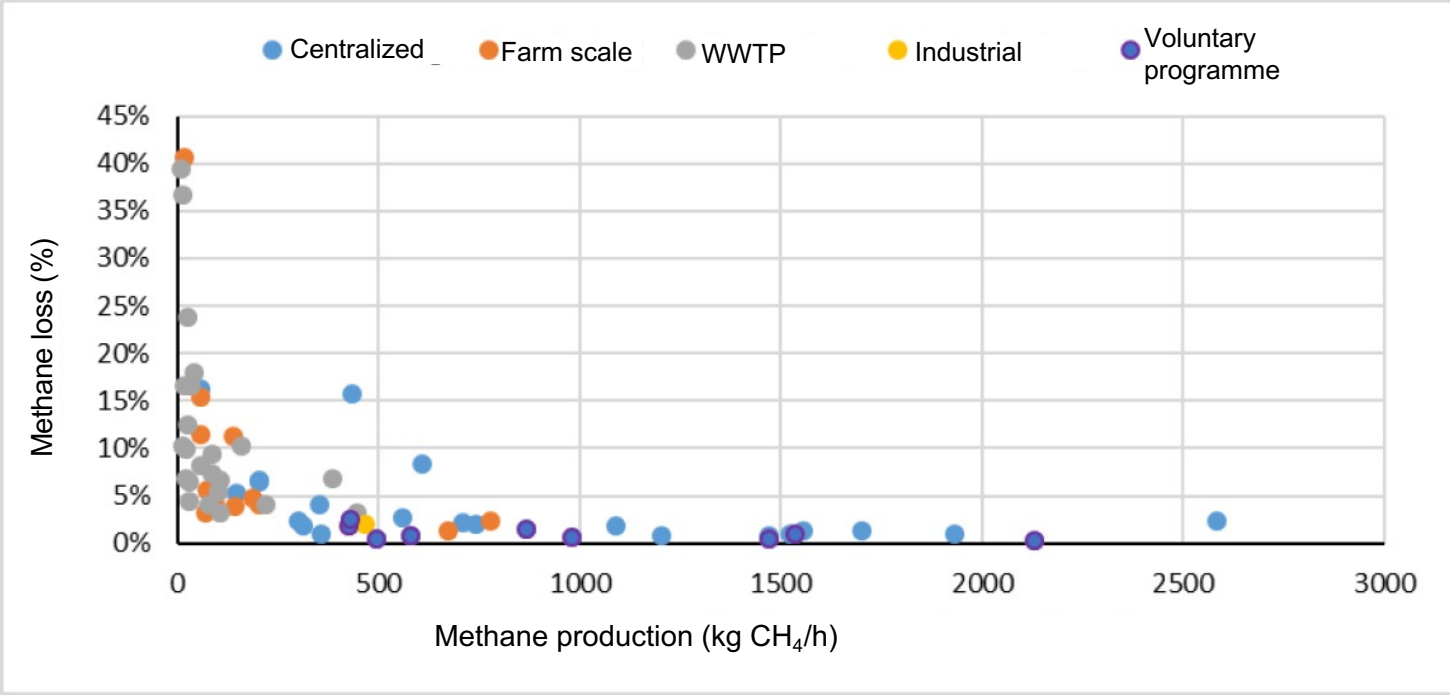
The method is:

- Well-documented (control test and international comparison tests)
- Certified
- Applied at many different sources

Whole site methane emission (kg CH_4/h)



Methane loss (% of methane production)

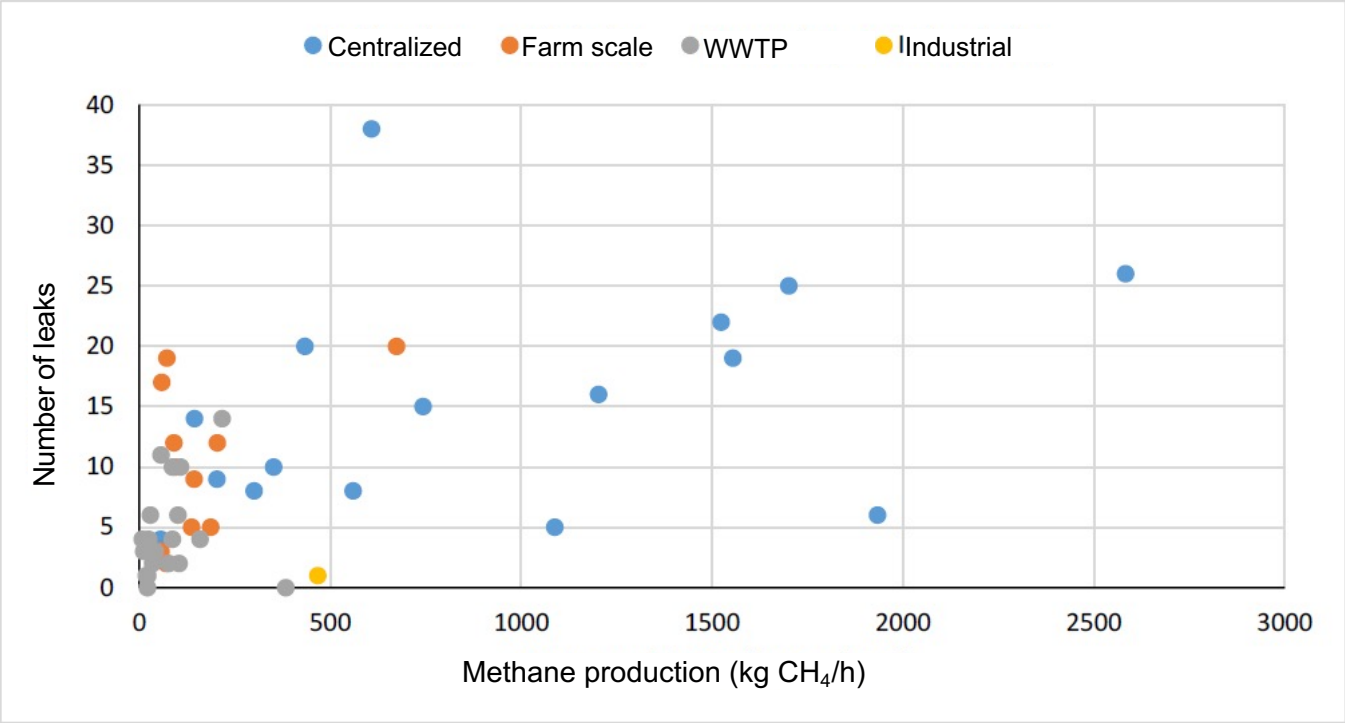


Production weight-based methane loss (%)

Plant type	Number of plants	Emission factor (%)
Centralized agricultural plants	29	1.9
Farm scale plants	15	3.9
Industrial plants	1	2.0
Wastewater treatment plants	24	7.7
All types	**69**	**2.5**

Rapport: Målrettet indsats for at mindske metantab fra danske biogasanlæg

Identified methane leakages

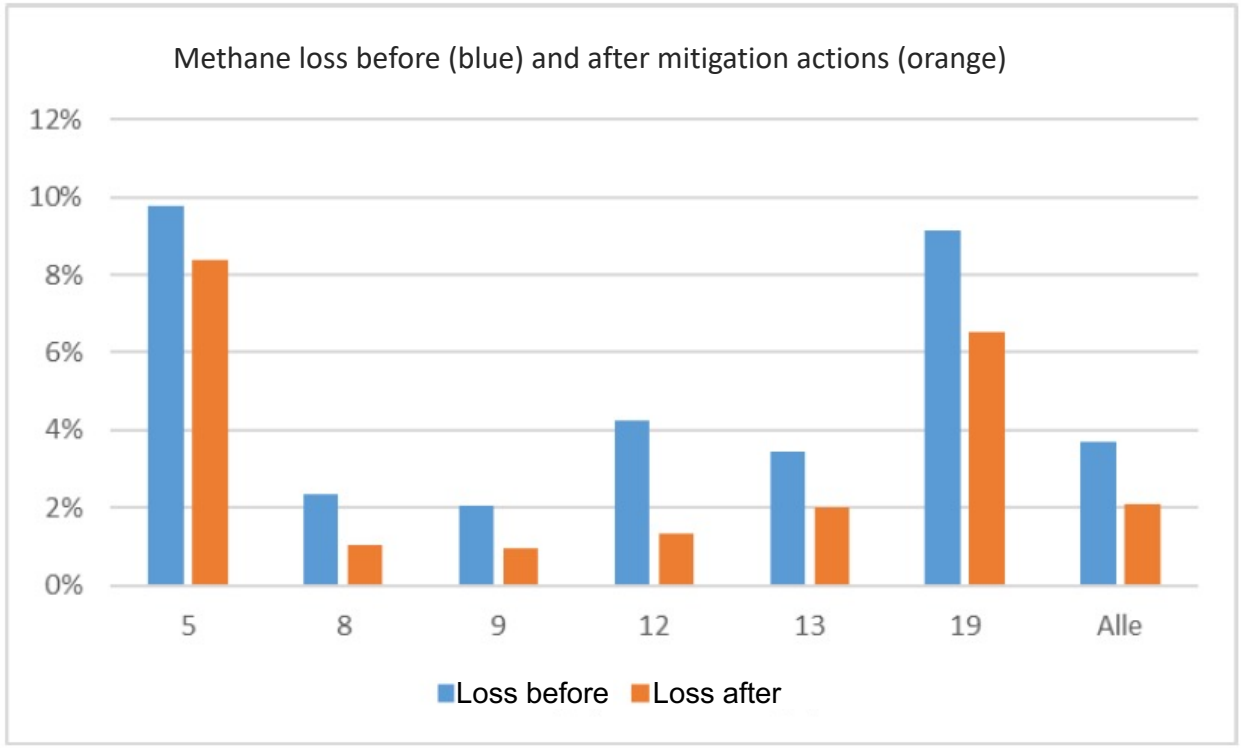


Rapport: Målrettet indsats for at mindske metantab fra danske biogasanlæg

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)

Measured effect of emission reduction actions



- All 6 plants reduced methane loss
- Reduction in emission were equal to:
  - 1,5 mio. Nm^3 methane/år
  - Increase in revenue of app. 1 mio. €/year
  - 29.000 tons CO_2-eq./year
  - 3.300 (Danish) person equivalents (GHG)

Rapport: Målrettet indsats for at mindske metantab fra danske biogasanlæg

Conclusions

- High variation in methane emission (kg CH_4/h) and methane loss (% of production) between 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
- Focus on methane loss can reduce emissions significantly
- In some cases, emission reducing actions can pay for themselves (positive NVP 10yr, feasibility studies at some of the plants)
- It is possible to emit less than 1% (national target set by Danish biogas producers)

We need to measure our GHG emissions

> We need to start measuring our GHG emissions to track the impact of green initiatives and emission reduction technologies, as society invests heavily in a fast green transition

Knowledge

To know our current emissions:

What, where, how much?

Mitigation

To monitor and document mitigating actions:

What works?

Cost

To ensure cost-efficiency of mitigating actions

Is it worth it?

Impact

To improve emissions models and impact assessments

Will we reach our targets?

Reporting

To correctly report on GHG and inform policy

Are we making the right choices?

Development of new measurement technology and incentive

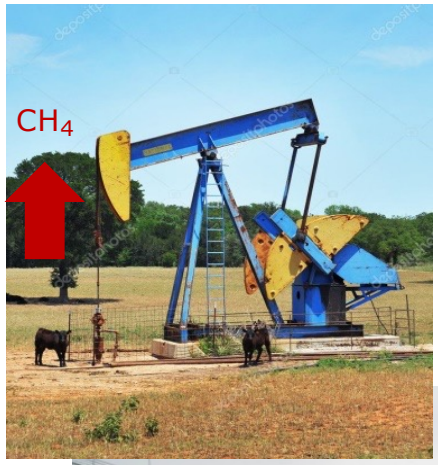
- Development of gas sensors
  - Multiple gases
  - High sensitivity and fast response
  - Robust
  - Light weight
  - Affordable

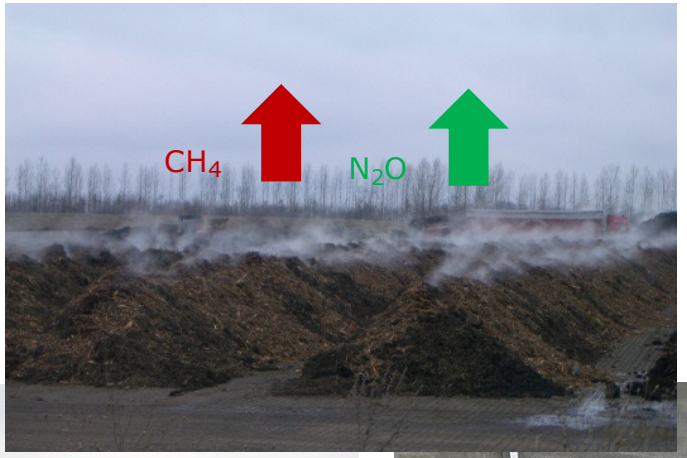
- Development of new measurement approaches
  - Tracer based methods
  - Drone-based methods
  - Continuous measurement method
  - Fence-line monitoring systems
  - Leakage

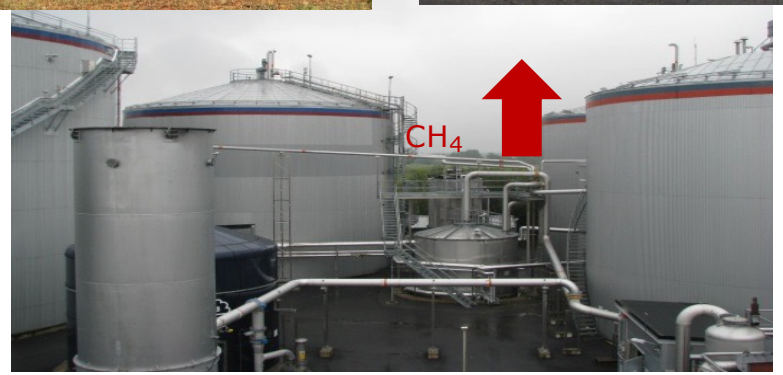
- Development of incentive
  - Lack of knowledge about emissions
  - Lack of attention of the problem
  - Global impact – not driven by local environmental effects
  - Lack of regulation
  - Lack of potential mitigation actions, associated costs and effect

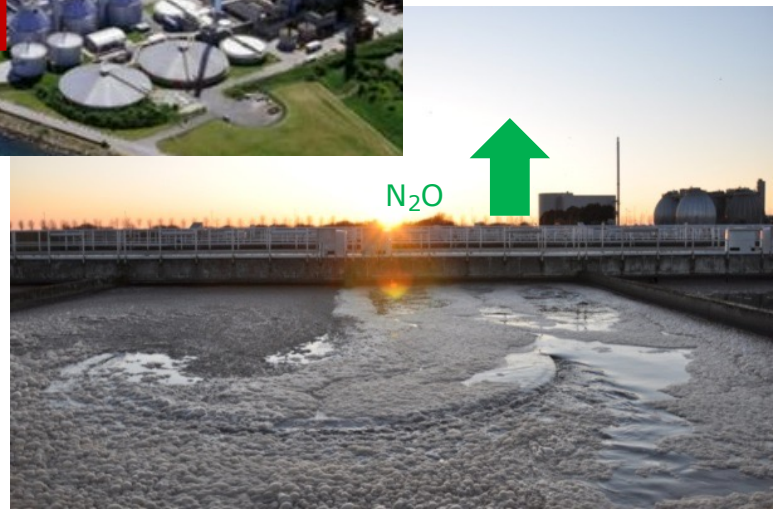
Many other sources and GHGs

- Many sources, different gases
- Large and complex
- Diffusive and dynamic by nature
- Difficult to locate and quantify









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Thank the Danish Energy Agency

Link to the Danish biogas report:

https://ens.dk/presse/ny-rapport-om-metantab-fra-danske-biogasanlaeg

GAS EMISSION FROM STORAGE FACILITIES BEFORE AND AFTER BIOGAS

AARHUS
UNIVERSITY
TECHNICAL SCIENCES

WEBINAR SUSTAINABILITY AND METHANE LEAKAGE
21 APRIL 2022

ANDERS PETER S. ADAMSEN
SENIOR RESEARCHER

BACKGROUND

Emission of:

- methane, CH_4
- ammonia, NH_3 (a small part can be oxidized to N_2O)
- nitrous oxide, N_2O (direct and indirect emission from NH_3)

Global Warmning Potentials non-fossil CH_4 (IPCC Assessment report 6)

- GWP_{100}: 27 years
- GWP_{20}: 81 years

Significance: Methane might be more important as a GHG in the near future. Luckily, its lifetime is relatively short in the atmosphere (12 years)

WHOLE CHAIN IS IMPORTANT

Important to measure emission from the whole chain:

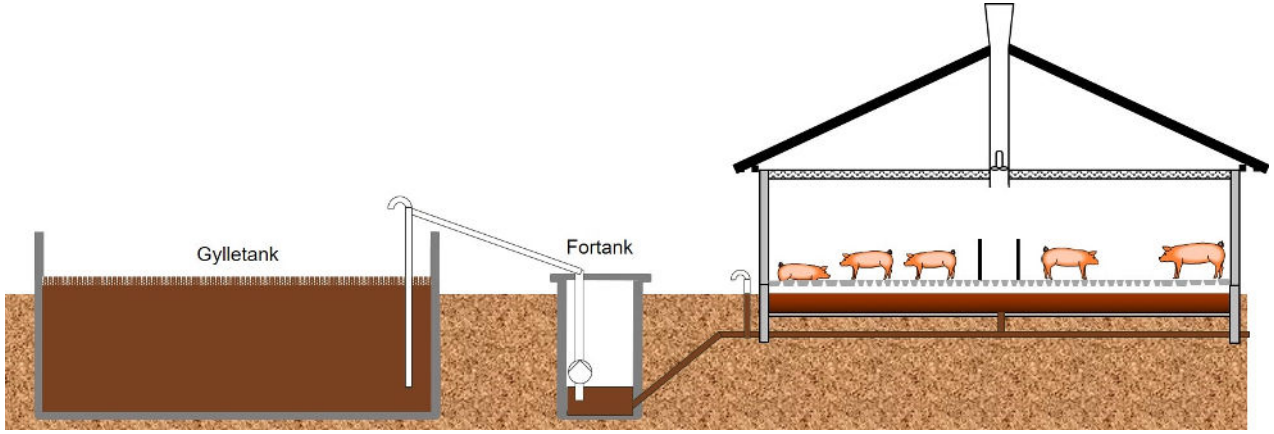
- Animals – enteric CH_4
- Manure
  - barns
  - storages
  - biogas plants
  - storage of digestates
  - application on the fields

Reduction in one place -> can increase downstream emission

FREQUENT FLUSHING OF SLURRY - METHANE

Example with finishing pigs – simulation with Arrhenius type model

- Fully slatted floors
- Slurry production, (0.9 cm/day)
- Temperature
  - barn: 19 °C
  - storage: ambient (almost)
  - from May to April (average 6 – 7 months



Flushing intervals (days)	HRT (days)	Without biogas (kg CH_4 / ton slurry)			With biogas (kg CH_4 / ton slurry)		
		Barn	Slurry tanks	Barn & Storages	Barn & pre-tanks	Slurry tanks	Barn and storages
35	21	2.3	2.5	4.8	2.5	0.1	2.6
7	7	0.9	3.0	3.9	1.1	0.2	1.3

LOSSES BIOGAS PRODUCTION

Leakages on a biogas plant can affect the “greenness” of process.

- In Denmark we aimed for a loss of < 1% of the produced biogas
- In reality it is higher, ~ 2.5%
- Especially important when using energy crops

GAS EMISSIONS FROM DIGESTATE

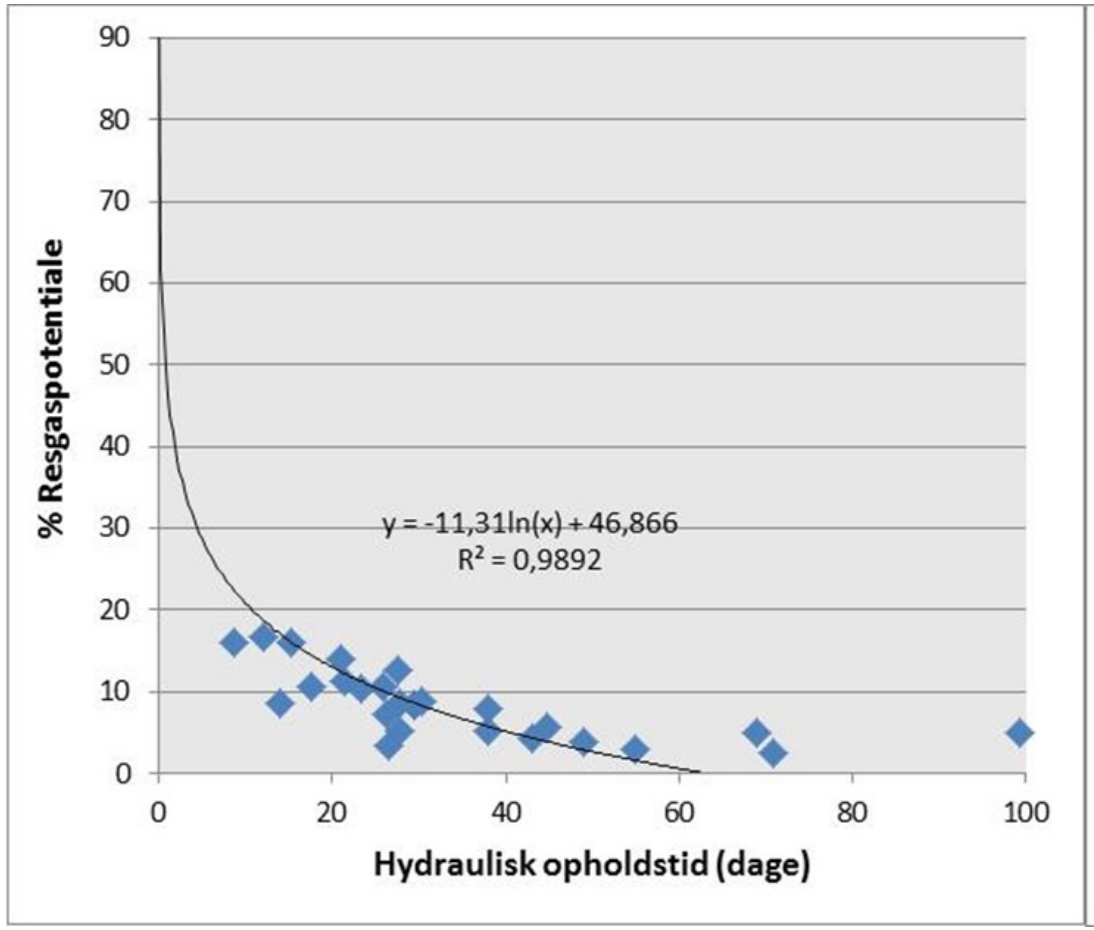
Digestates applied on the fields emit more NH_3 than un-digested slurry due to:

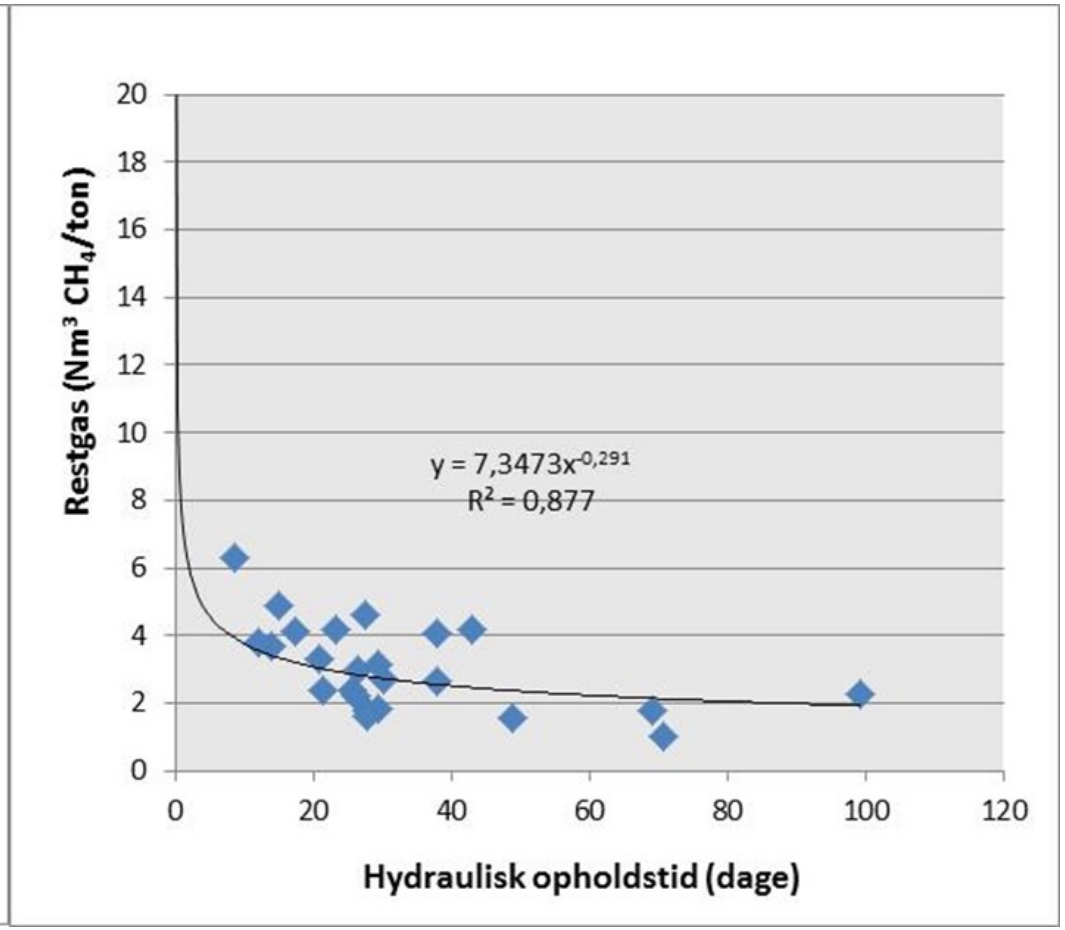
- conversion of org-N into NH_4^+
- addition of N in feedstock to the biogas plant
- higher pH in the digestate

In Denmark, digestate should be applied on the fields using one of the following technologies:

- acidified,
- injected in open slot (grass) or closed slot (soil without crops)
- trailing hoses and incorporated into the soil within 4 hours

RESIDUAL METHANE PRODUCTION





METHANE EMISSION FROM DIGESTATE

Not all of the residual methane is produced:

- Lower temperature -> higher CO_2/CH_4 ratio
- low-dose acidification can reduce CH_4 production

Headspace gas from covered slurry tanks or lagoons can be reduced by:

- flaring (thermal combustion of gas)
- oxidized in soil or biofilter (long retention times)

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METHANE LEAKAGE FROM BIOGAS UPGRADING TECHNOLOGIES

AGENDA

1. Introduction
2. The environmental impact of methane slippage
3. The 4 different upgrading technologies
4. Comparison of the upgrading technologies
5. Methane removal in off gas
6. Conclusion
7. Questions

INTRODUCTION

- Engineering company specialized in air- and gas purification systems.
- Located in Glostrup, Denmark.

- Scrubber systems, biogas upgradi
  NH_3 separation & concentration,

Alexander Ryhl

Global Business Engineer

Biogas industry since 2016

ENVIRONMENTAL IMPACT OF METHANE SLIPPAGE

- Methane slippage: The percentage of inlet biomethane that does not come out as product gas.

- Methane slippage has two environmental effects:

1. Methane is a greenhouse gas
   - Methane as a greenhouse gas is more than 25 times as potent as CO_2[1,2]

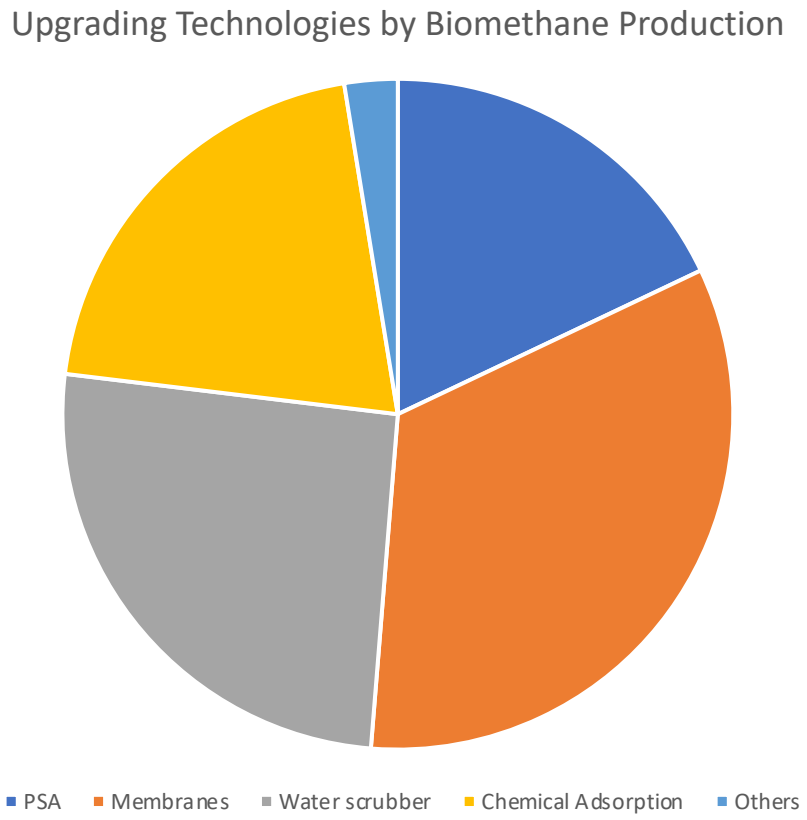
2. The methane loss is lost energy that would replace natural gas
   - Each m^3 of methane lost would have replaced a m^3 of natural gas, which must now be produced.

1) EPA, 2021
2) DGC, 2018

BIOGAS UPGRADING

- In general, we see four different upgrading technologies:[3][5]

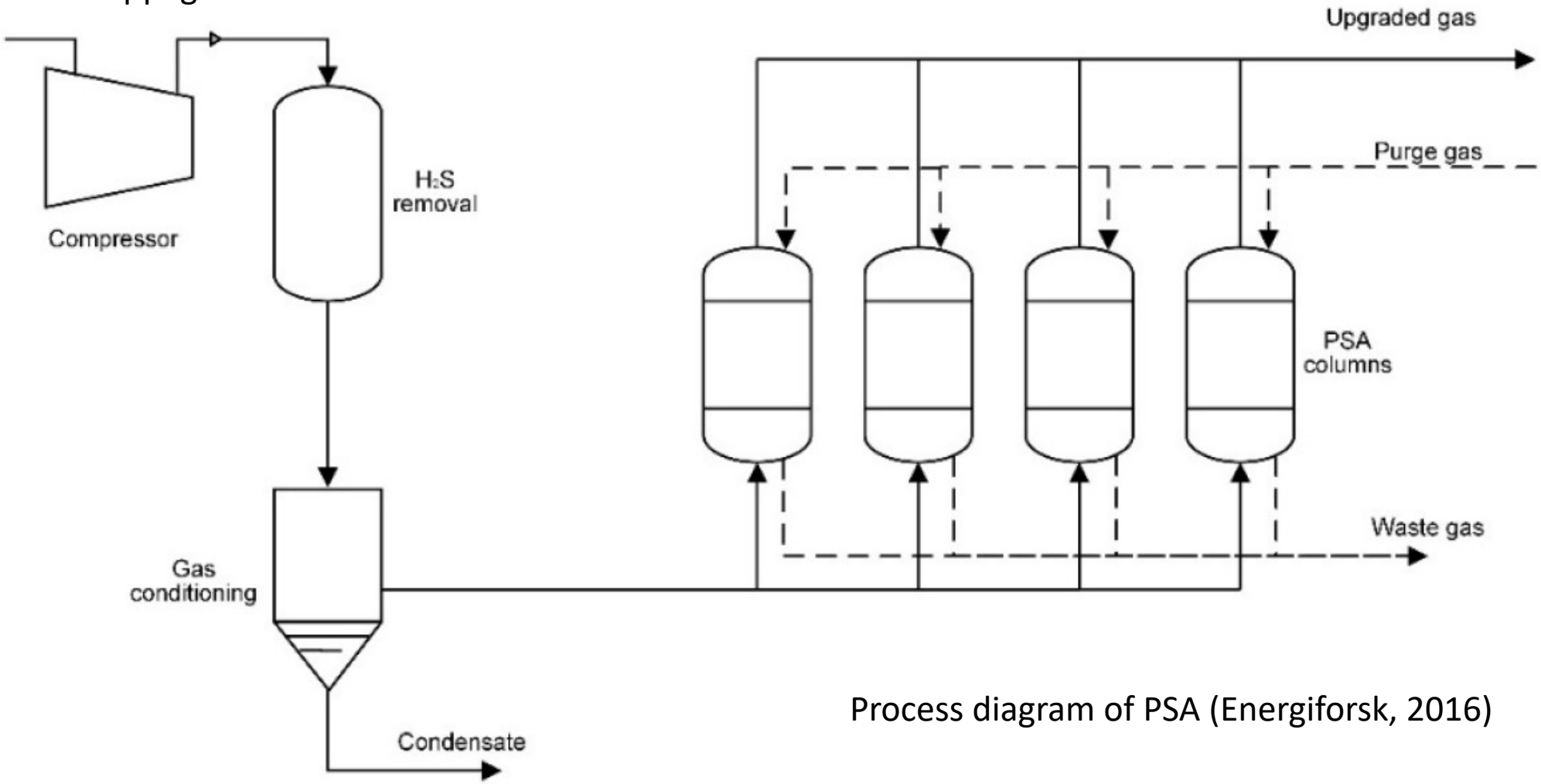
1. Membranes
2. Water Scrubbers
3. Chemical Adsorption
4. PSA
5. Others



3) Energiforsk, 2016
5) Biogas World, 2020

PRESSURE SWING ADSORPTION (PSA)

Methane slippage: 1.8-2 % [4]

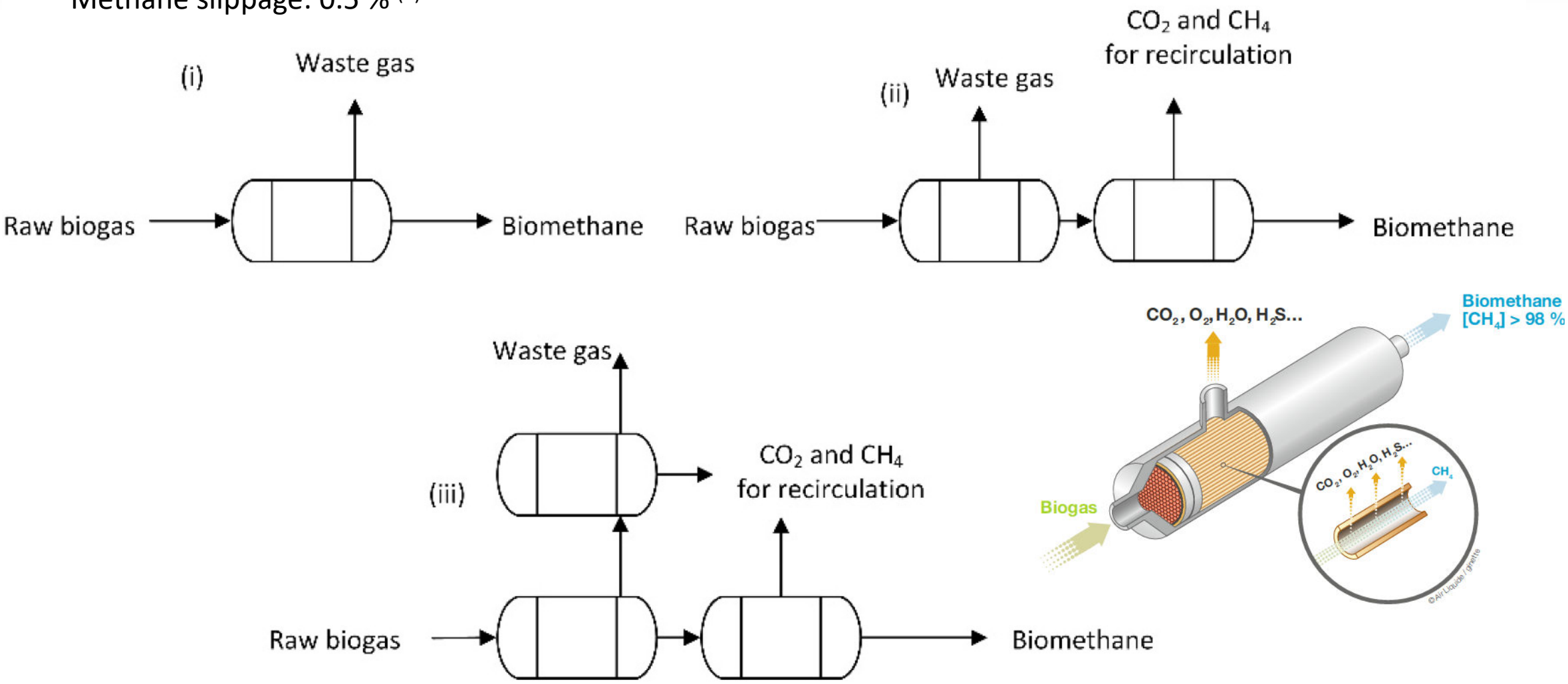


Process diagram of PSA (Energiforsk, 2016)

4) SGC, 2013

MEMBRANES

Methane slippage: 0.5 % (2)

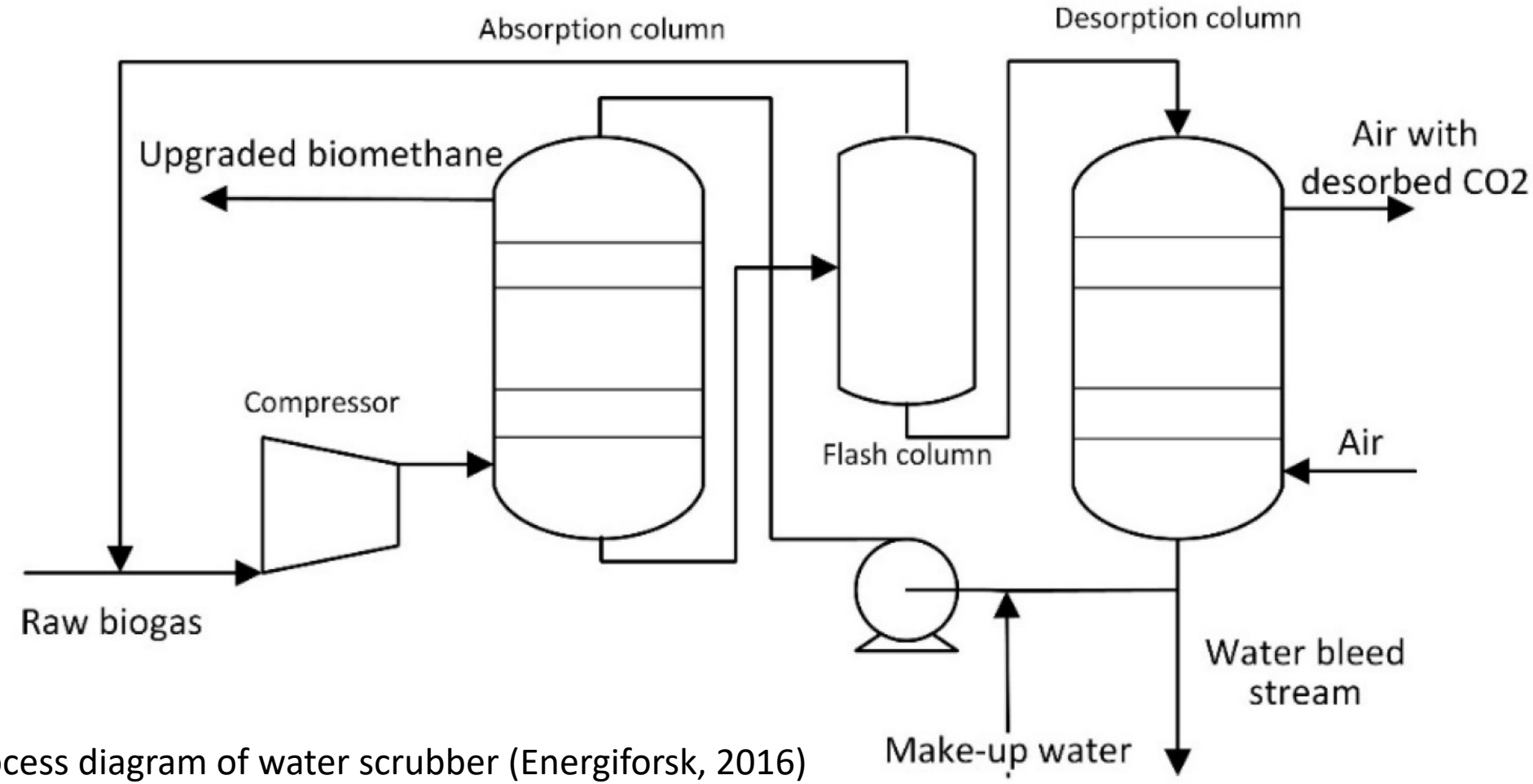


Process diagram of membrane (Energiforsk, 2016)

2) DGC, 2018

WATER SCRUBBING

Methane slippage: 1.5 % [2]



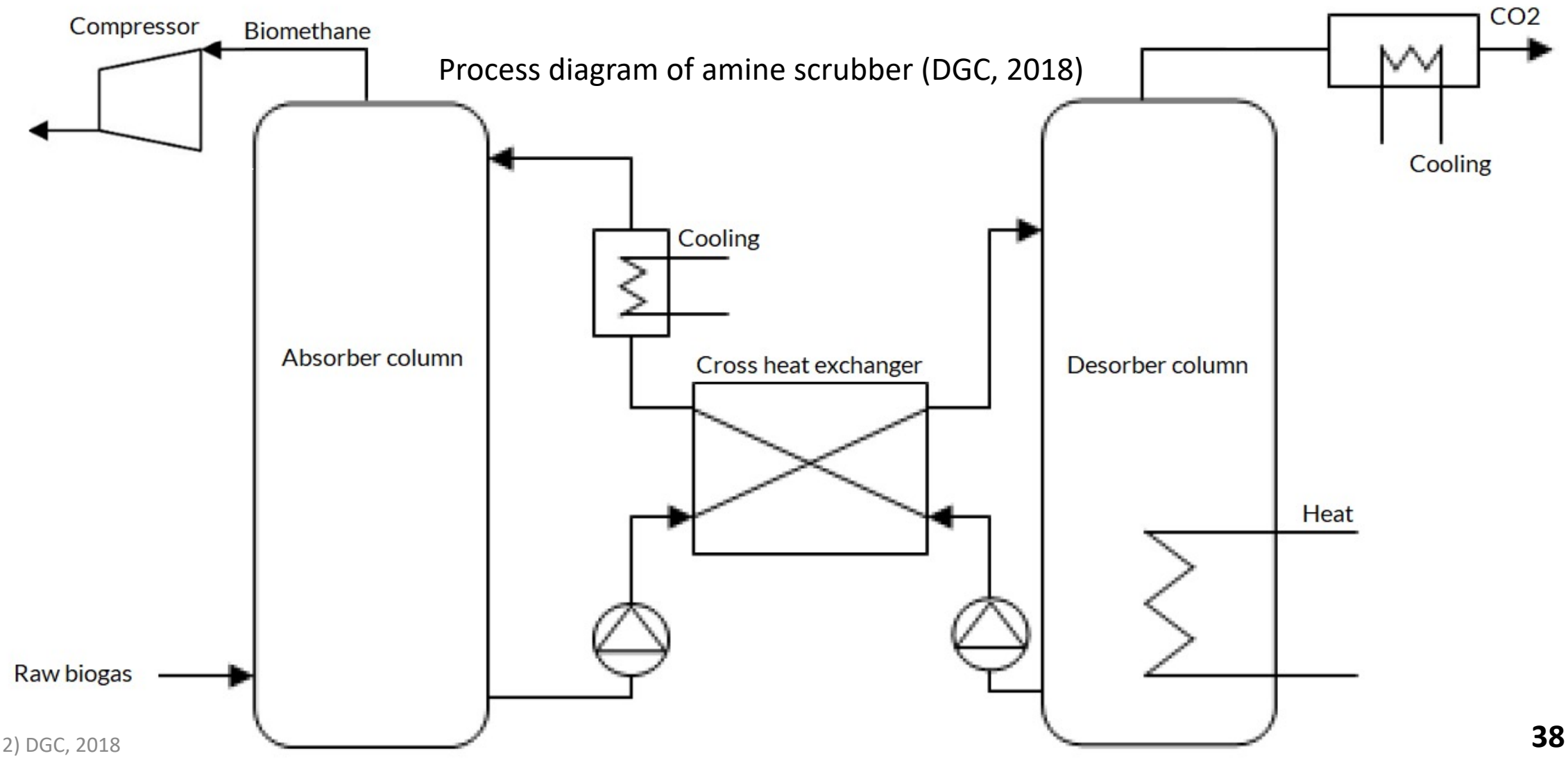
Process diagram of water scrubber (Energiforsk, 2016)

2) DGC, 2018

AMINES

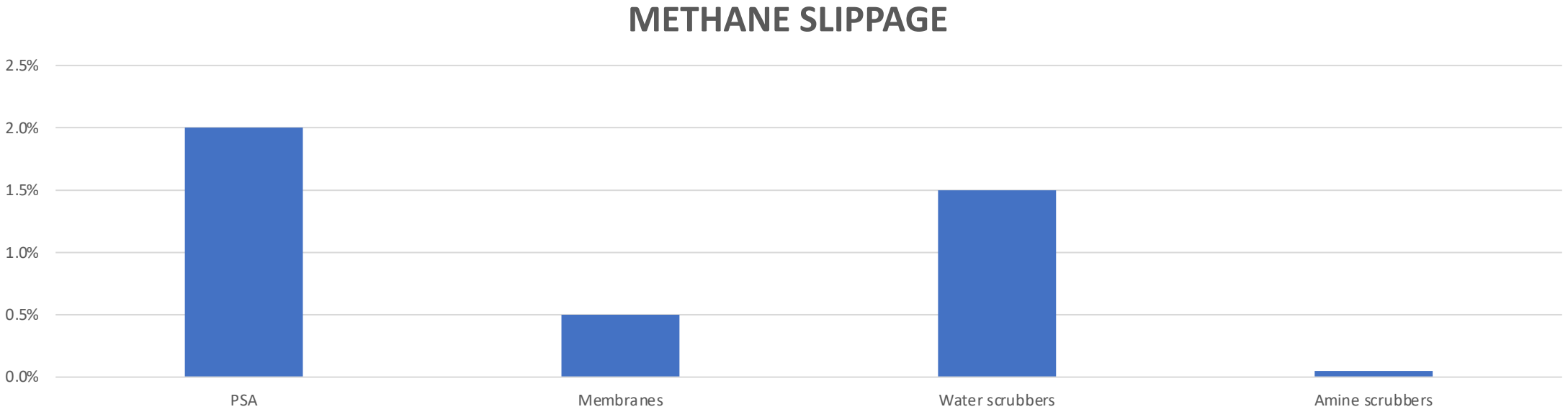
Methane slippage: 0.05 %[2]

Process diagram of amine scrubber (DGC, 2018)



2) DGC, 2018

COMPARISON



UPGRADING	METHANE SLIPPAGE (2,4)
PSA	1.8 – 2 %
Membranes	0.5 %
Water scrubbers	1.5 %
Amine scrubbers	0.05 %

2) DGC, 2018
4) SGC, 2013

METHANE REMOVAL IN OFF GAS

- Regenerative Thermal Oxidation (RTO)[3]
  - Operates at 750 – 1000 °C to combust the off gas.
- Regenerative Catalytic Oxidation (RCO) [3]
  - Like RTO but with a catalyst bed to run at 250 – 500 °C
- Genset[3]
  - Small combustion engine running on off gas + a fraction of the biogas
- Cryogenic Distillation[3]
  - Performed at 18 bar(g) and -24 °C, creates liquid CO_2 with <10 ppm CH_4

2. The methane loss is lost energy that would replace natural gas
   - Each m^3 of methane lost would have replaced a m^3 of natural gas, which must now be produced.

3) Energiforsk, 2016

CONCLUSION

- Figures of methane slippage is “easy” to judge from:
  - PSA 1.8 – 2 %
  - Membranes 0.5 %
  - Water scrubber 1.5 %
  - Amine scrubber 0.05 %

- Need to look at the specific situation
  - What heat is available?
  - Is there a need for liquid CO_2?
  - Is it upgrading of landfill gas?

Questions?

REFERENCES

1) U.S. Environmental Protection Agency, (2021, June 30). https://www.epa.gov/. Retrieved from https://www.epa.gov/gmi/importance-methane

2) DGC. (2018). Metantab ved opgradering. Danish Gas Technology Centre.

3) Energiforsk. (2016). BIOGAS UPGRADING – TECHNICAL REVIEW. Energiforsk.

4) SGC. (2013). SGC Rapport 2013:270. Malmö: Svenskt Gastekniskt Center AB.

5) Biogas World. (2020). Biomethane Market Intelligence Report – North America and Europe