Methane emission mitigation strategies

Information sheet for biogas industry

Content

1 Preface

The biogas technology delivers renewable energy in form of biogas and contributes as a replacement for fossil fuels to climate protection. While the primary effect of biogas production is climate protection, greenhouse gas (GHG) emissions in form of methane can be emitted into the atmosphere, e.g. due to leakages or special events in operation. Due to the global warming effect of GHG emissions, the release of GHG needs to be rapidly reduced, also in production of renewable energies. It is important to minimize the emissions from biogas to ensure a climate protective technology.

Additionally, with the new Regenerative Energy Directive (RED II) in December 2018, which must be implemented into national laws until 2021, some biogas-producing plants must proof their GHG savings compared to fossil fuels. With that, the need to reduce GHG is even more pronounced in the European biogas industry. The current situation in Europe is described in the following section below (Section 2).

Within this information sheet, EBA states, besides various positive effects of using biogas (Section 3), the importance of minimizing the methane emissions from biogas industry. For that, this information sheet summarizes potential emission sources and addresses how to minimize methane emissions from biogas plants (Section 4). Additionally, several ongoing initiatives for reducing methane emissions in European biogas sector are introduced (Section 5).

This document was built together with and reviewed by the project consortium from the research project "EvEmBi"- Evaluation and reduction of methane emissions from different European biogas plant concepts (funded within 11th ERA-NET Bioenergy Joint Call/ 1st add. Call of BESTF3). The project partners involved in the EvEmBi project are DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH, University of Stuttgart, Fachverband Biogas e. V., University of Natural Resources and Applied Life Sciences Vienna, BEST Bioenergy and Sustainable Technologies GmbH, Abwasser und Abfalltechnik GmbH, Kompost & Biogas Verband Österreich, Ökostrom Schweiz, Bern University of Applied Sciences, Oester Messtechnik GmbH, Research Institutes of Sweden, Avfall Sverige, Svenskt Vatten, and Technical University of Denmark. The partners were nationally funded by the Federal Ministry of Food and Agriculture Germany via Agency for Renewable Resources e. V. (FNR), the Austrian Research Promotion Agency (FFG), the Swedish Energy Agency, the Swiss Federal Office of Energy, and the Technical University of Denmark.

2 Current situation in Europe and perspectives

The European biogas and biomethane sector have been continuously increasing over the past decade. By the end of 2018, there were 18,202 biogas plants and 610 biomethane plants Europe-wide. Figures 1 and 2 show the evolution of biogas and biomethane plants starting from 2009 and 2011, respectively. In the year 2018, the number of biogas plants in Europe has increased by 2% and the number of biomethane plants by 13%, showing the already mature character of the biogas market and the rapidly evolving biomethane market.

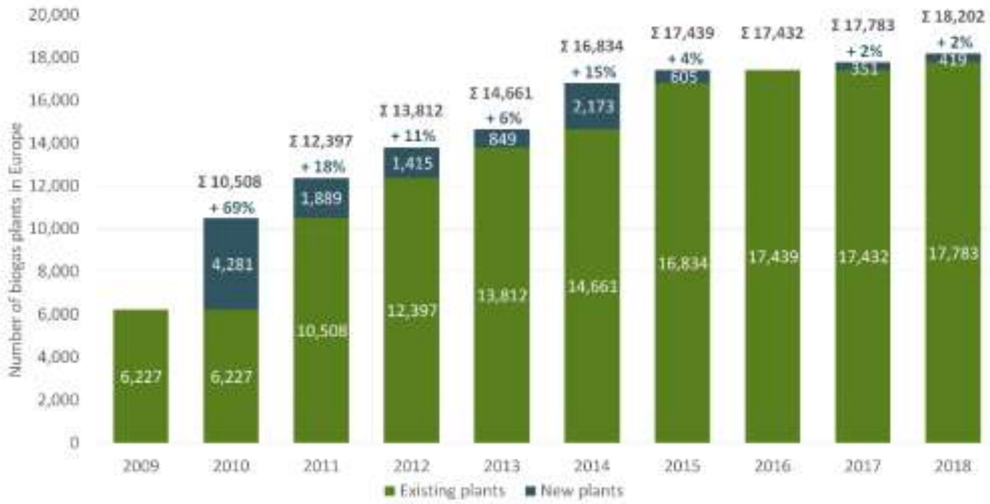

Figure 1: Number of bigoas plants in Europe (source: EBA)

Figure 2: Number of biomethane plants in Europe (source: EBA)

Following the European Parliament's election in 2019, new Commissioners entered the office in October 2019. As one of their first acts, they introduced the concept of 'European Green Deal' that is the flagship initiative of the current Commission 2019-2024. The idea is to make Europe the first climate-neutral continent in the World by 2050. Consequently, all relevant legislation will be reviewed and possibly revised. Additional pieces of legislation will be put forward, like the Climate Law that writes into law the goal set out in the European Green Deal. Also, the targets from the RED II will be reviewed; the GHG emissions reduction target will likely be increased to 50-55% by 2030.

The current RED II has also introduced stringent EU-wide sustainability criteria for solid, gaseous and liquid biomass. Biogas produced in installations above $2MW_{th}$ must reach certain GHG emissions savings compared to fossil fuels in order to be accounted towards the overall renewable energy target of 32% (review in 2021) by 2030. The requirements depend on the energy sector and increase gradually over time. The emission savings can be calculated by using the default values included in Annex VI of the RED II or by using own actual values. Member States can further tighten the criteria at the national level and impose the requirements on small plants, below $2MW_{th}$.

Given the above-mentioned sustainability criteria and the implementation of the 'European Green Deal' in coming years, the need to reduce GHG is now even more pronounced in the European biogas industry.

3 Beneficial effects of using biogas and biomethane

Biogas is produced mainly from organic residues and energy crops. As other renewable energy sources, biogas can contribute to the reduction of GHG emissions from different sectors, as it can be used for transport fuel, to produce heat and power or as a raw material for futher applications. The competitive advantage of biogas compared to other renewable sources is that it takes advantage of the existing infrastructure and it can be stored, providing an alternative to intermittend generation from other sources, such as solar and wind, and ensuring security of supply. To illustrate, agricultural biogas plants in Switzerland have reduced methane emissions by more than 50,000 tons of CO_2 equivalent by using about 1 million ton of manure in 2019 [15].

Digestate is the remaining part of the degraded biomass after biogas production: it is stable organic matter rich in various nutrients (N, P, K). Depending on the feedstock used for biogas production, digestate is directly usable as organic fertilizer in the same way raw animal slurries are spread on fields in agriculture. It can also be further upgraded to recover high quality mineral nutrients. Digestate use as organic fertilizer displays multiple advantages: it allows reuse of nutrients and substitutes mineral fertilizer of fossil origin.

Additionally, biogas and biomethane functions also as a driver for rural development. The recovery of organic residues, carbon and digestate, combined with other options such as the use of secondary crops for biomethane production, can contribute to the development of a more efficient farming sector, which is the main economic activity of many rural areas.

4 Emissions sources and recommendations for reducing emissions from biogas plants

As methane is a very potent GHG with a high global warming potential (GWP of 28 for a 100 year period [5]), these emissions should be minimized. On a biogas production plant, very different emission sources may occur. There are areal sources, point sources and sources, which occur only at certain operational conditions. The most common and relevant sources are:

- Emissions from tanks upstream of the digester
- Leakages at gas holders and gas holder fixation
- Emissions from safety valves (pressure relief valves)
- Emissions from open or not gas-tight covered digestate storage tanks

- Emissions from biogas utilisation units (e.g. Combined Heat and Power (CHP) and biogas upgrading units)

Besides the abatement of climate change, minimizing methane emission has several additional beneficial effects. This includes safety aspects, finances and odour problems. If the concentration of biogas in the air is between 6 and 22 vol%, or for biomethane between 4.4 and 16.5 vol%, there is a risk of explosion in the presence of an ignition source (explosive range, explosive atmosphere). Avoiding methane leakages, is therefore also important for safety aspects. Next, plant operators aim to use the largest possible amount of methane produced, as this energy containing gas is their main source of income. Small losses of methane can lead to considerable financial losses. Last, although methane is an odourless gas, reducing methane emissions can also reduce the emissions of odorants, such as sulphur compounds.

In the following, the most relevant emission sources and effective mitigation measures to avoid or minimize the emissions from these sources are described. A more detailed description of the emission sources is given in [6] and references therein. A detailed description about the different measurement methods to detect and quantify emissions at biogas plants is described in [7].

4.1 Receiving and pre-stages upstream of the digester

Depending on several conditions (type of feedstock, storage time, pre-processing, temperature, pH value, etc.), emissions from receiving tanks or buffer tanks can occur. While the emissions from solid feedstocks including silage is negligible, manure storage, in particular cow and pig manure, causes emissions. Also, not gas-tight mixing or hydrolysis tanks where feedstocks are mixed before feeding to the digester cause emissions. The project AcEta [8] investigated the emissions from such pre-stages on agricultural plants with the result that these tanks can cause quite high emissions. On waste management plants, emissions from the receiving stage or during pre-treatment of the received waste can occur. The air is emitted from those pre-treatment stages via biofilters, anyhow methane emissions may occur [9].

Emissions in receiving stage can be avoided, e.g., by gas tight covering of open tanks, appropriate temperature and pH value. For liquid manure, it is recommended to bring it directly into the gas-tight biogas plant to avoid emissions and achieve a high biogas yield.

4.2 Digestion process

The main digestion process takes place in gas-tight systems. Nevertheless, emissions occur via diffusion through gas holder membranes, leakages or pressure relief valves. It should be noted that large leakages and emissions via safety valves belong to the OTNOCs (Other Than Normal Operation Conditions). These emissions must be avoided and should not occur during normal operation condition of a biogas plant.

The first recommendation to reduce methane emissions is addressed to plant designers. Careful consideration should be given to the orientation of low-emission operation already in the planning phase, including the design of the tanks, the dimensioning of the gas pipes, etc. The diffusion through gas holder membranes can, furthermore, be minimized by performing regular maintenance of the foils.

Leaks frequently occur at roof construction ([6] and references therein). For membrane domes, special attention should be paid to the transition between digester wall and membrane dome. In addition, rope feed-throughs for the submerged agitators of the digester often build leakages. A regular leak detection can help to identify leaks at an early stage in order to repair them and avoid emissions. However, leakages may also occur in other parts of a biogas plant, e.g. gas pipelines. To identify those, also a regular leakage detection will avoid emissions. Especially, flange joints on pipes with some movement (e.g. at CHP or upgrading unit) are weak points and should be checked for leaks regularly. One idea, for example, is to introduce a voluntary system that includes an obligation for regular self-inspection. Regular checks from external measurement providers can also be part of such a system. In Denmark and Sweden, such a voluntary system was already successfully implemented [10, 11].

The safety valve should open at overpressure in the digester, but only as last option. In any case, the gas flare must be started before the safety valves respond. Investigations by [12] have shown, however, that there are biogas plants where safety valves regularly emit biogas. A frequent cause is, for example, that the gas holders are operated with too high filling levels. In case of heating, e.g. by solar radiation, the gas storage capacity decreases, the filling level rises above a critical value and the overpressure safety valves redundant release biogas. It is therefore very important that the filling levels are not too high, to compensate weather effects. A filling level of 50% is recommended [6]. In [12], emissions could effectively reduced by lowering the filling level to 50%. However, also the flare should turn on automatically (preferably regulated via filling level), so that emissions from the safety valves are practically impossible.

4.3 Biogas residue/ digestate storage

Downstream of the digester, the methane formation process may continue in the biogas residue. Therefore, it is important reaching nearly full degradation of digestible organic matter. The most suitable way to handle residual biogas is to keep it in a gas-tight covered digestate storage tank that is connected to the gas system. Here, the biogas residue can be allowed to cool, and the methane formed taken care of. Another option to reduce methane production in the biogas residue is to assure that the temperature of the biogas residue is reduced, since methane production decreases at temperatures below 17°C.

4.4 Biogas utilization

During biogas utilization, methane emissions can occur at a biogas plant. There are mainly two types of gas utilization: combustion of biogas to generate heat and electrical power by a CHP unit and upgrading of biogas to biomethane. In certain operational modes, e.g. malfunction of CHP, the excess gas must be burned via a biogas utilization like a flare or burner, so that the methane is converted to carbon dioxide and water.

4.4.1 Combined Heat and Power (CHP)

The CHP builds a major source for methane loss at a biogas plant. The exhaust gas from CHP still contains methane due to incomplete combustion. Recurring maintenance can significantly reduce emissions. In extreme cases, the emissions can be reduced to a minimum by installation of a thermal post combustion unit. In addition, the use of a selective catalytic reduction (SCR) catalyst, for reduction of NOx and other treatment measures is in discussion to reduce methane emissions as well, as different engine adjustments can be used in this case. Anyhow, regular measurements at CHP exhaust and a good documentation of the engine settings can give evidence, which engine settings should be used for an emission friendly operation.

4.4.2 Biogas upgrading

In addition, biogas upgrading units can be a source for methane emissions. Due to the technical limitations and operational performance of the upgrading technique and its settings, there can be to a more or lesser extend methane left in the separated carbon dioxide stream (the exhaust gas). Moving parts and machinery, e.g. compressors, within the upgrading unit are often subject to emissions over time. It is therefore important to follow up on the upgrading unit performance and regularly search for gas leaks on the equipment. Regular maintenance in accordance to recommended intervals and specifications are crucial. Additionally, a post-treatment of the exhaust gas can reduce methane emissions from this source.

4.4.3 Flaring

The flare should start automatically if the filling level is too high. This prevents the biogas from being released via the safety valves. To achieve the lowest possible emissions during flaring of excess gas, an enclosed flare or a gas burner is recommended. Another way to reduce methane emissions during flaring is to use an adjustable flare to prevent an unnecessary amount of gas from being flared. Methane emissions can also occur if the gas/air mixture ratio is incorrect [10].

4.5 Post-treatment digestate

During post-treatment like post-composting of the digestate and solid-liquid separation, emissions may occur. The emissions can be minimized by sufficient aeration of the digestate and an appropriate adjustment of the material structure.

4.6 Overview of mitigation measures on biogas plants

There are several technical and organizational measures to reduce the emissions from biogas plants. Technical mitigation measures are real interventions on the plant, e.g. the installation of new components or maintenance. Technical measures are mostly in connection with costs. Organizational measures describe the change of action sequences during plant operation and can also represent very efficient mitigation measures. From [6] and the experiences of the EvEmBi project consortium, the most relevant mitigation measures are listed below.

Technical mitigation measures:

- Sealing of leakages
- Gas-tight covering of tanks, e.g. storing or mixing tanks
- Installing an exhaust gas treatment
- Considering emissions already during planning of the biogas plant, e.g. usage of emission friendly technology and right dimensioning of biogas pipes
- Regular replacement of aged gas holder membranes

Organizational mitigation measures:

- Regular leakage detection
- Leakage detection/ emission measurements after renewal of plant components, e.g. renewal of gas holder membranes → clarify if actions are necessary
- Gas holder filling level preferably at 50 %
- Regular maintenance of CHP
- Regular maintenance of openings for ropes
- Adjustment of substrate feeding before planned maintenance
- Mass balance calculation to identify losses → clarify if actions are necessary
- Consideration of seasonal effects
- Sufficient aeration during post-treatment
- Documentation of emission detection and quantification measurements → clarify if actions are necessary
- Low-emission adjustments, e.g. CHP adjustment
- Analysis of residual gas potential → clarify if actions are necessary

To support the implementation of the technical and, in particular, the organizational mitigation measures on the plant, it is very important to transfer the knowledge about methane emissions and their mitigation to plant operators. With this knowledge transfer and the consequent improvement of performance, e.g. by implementing regular self-inspection, the emission can be reduced. Some important secondary mitigation measures which enable the comprehensive performance of the primary measures (technical and organizational) are listed below. Initiatives to implement these secondary mitigation measures in Europe are announced in the following section.

Secondary mitigation measures:

- Knowledge transfer to operators, e.g. workshops, publications
- Cost-benefit analysis for single mitigation measures
- Implement Voluntary System for self-inspection

5 Activities of the biogas industry to reduce methane emissions

The biogas industry is aware of the importance of methane emissions and has been working on various reduction measures for years.

Due to the economic, safety and environmental significance of methane losses, biogas plants are now planned, built, and operated with the focus to minimize methane losses. The state of the art of biogas plants and affected plant components (gas tight covers, permeation of gas holder membranes, gas flare etc.) has developed significantly in the past. The manufacturers of biogas plants are continuously working on further improvements. Measures to reduce methane emissions have been included in technical regulations, e.g. in the TRAS-120 [13] in Germany.

As an example for ongoing technical development, the membranes of the gas holders have been optimized to such an extent that the previous permeation limit value of 1,000 ml/(m² d bar) has been reduced to 500 ml/(m² d bar) [16]. There are also further detailed requirements for the design of the gas storage facilities and their connection to the digesters and storage tanks, as well as for monitoring methane emissions.

Many plant operators have discovered the special benefit of voluntary inspections of biogas plants for methane emissions with the aid of optical gas imaging (OGI) cameras and carry out these inspections voluntarily at annual intervals. Together with regular maintenance measures by qualified specialist companies, avoidable emissions can be controlled very well. The avoided biogas emissions may cover the resulting costs for the OGI camera inspection and maintenance and therefore may ensure a high acceptance in the branch.

Besides ongoing technical and organizational mitigation measures, the first voluntary monitoring systems to reduce methane emissions have been established successfully in Sweden, Denmark and Switzerland. The systems include a regular self-inspection and external measurement. Such a Voluntary System is able to improve the performance of the biogas technology. The overarching goals of such a system could be:

- Further improve the environmental performance of the biogas system
- Give plant owners support in performing a structured inventorying of their plant to detect emissions
- Give plant owners better knowledge about the size of the emissions from their plant and reduce any emissions and improve the economy

- Give the biogas industry better information and thereby greater credibility in relation to emissions
- Establish a better data basis with regard to actual losses

In Sweden, the Swedish Waste Management Association (Avfall Sverige) introduced a voluntary undertaking for biogas plants in 2007 [10], where the plants commit to work systemically to identify and reduce their emissions. One part of the voluntary undertaking is to regularly measure emissions at the plant to determine methane emissions and methane losses. Another part of the voluntary undertaking is to carry out regular and systematic leak detection work at the plant. The implementation of the system had clearly been successfully and has decreased methane emission by creating awareness by plant operators as well as provided useful data for proving the credibility of the industry. For more information, the report [14] reveals the positive development of introducing the voluntary agreement of self-inspection of methane emission in Sweden from 2007 to 2015 on biogas plants with upgrading.

In Denmark, the Danish voluntary methane monitoring programme for biogas producing facilities was launched by the Danish Biogas Association in autumn 2016 [11]. The programme is voluntary and methane emissions are monitored and reported to the Biogas Association in yearly reports. The reported data are compiled and reported by the association in an anonymized way. The Danish Biogas Association has set a sign-up success target of 90% participation and an overall goal of reducing the total methane loss from Danish biogas and upgrading plants on a national level to less than 1% by 2020. Similar to the Swedish system, the voluntary programme consists of two parts. The biogas plants carry out regular and systematic self-monitoring, where critical parts and components are examined for methane leaks. In addition, the plant is periodically reviewed by an external measurement company that quantifies the methane loss from identified leaks and sources at the plant. If quantification indicates that the plant's methane loss is higher than 2% of the annual production or more than 50 tonnes per year, the external consultant must suggest mitigation actions for each leakage or emission source. A new quantification must be performed within 1 year after.

In Switzerland, the agricultural biogas association Ökostrom Schweiz launched climate protection projects in 2010, starting with two biogas plants having their emissions measured by an external measuring company. In 2019, there were 35 agricultural biogas plants participating in the yearly emission measurements carried out with an on-site method. Biogas plant owners receive a report with all the measurement results of the whole biogas plant. The owners can use the report for deciding on mitigation measures.

EBA is part of the project consortium in the ongoing research project "EvEmBi"- Evaluation and reduction of methane emissions from different European biogas plant concepts (funded within 11th ERA-NET Bioenergy Joint Call/ 1st add. Call of BESTF3). In this project, with suggestions and support of the Swedish and Danish project partners (Avfall Sverige, Svenskt Vatten, Research Institutes of Sweden, and Technical University of Denmark), first steps are planned to implement similar Voluntary systems in other European countries. Currently, a document is being elaborated giving support for other European countries to implement their own voluntary systems by giving recommendations and advice for all European countries to advance to a Voluntary system for methane emission control in their own country.

In the EvEmBi project, further initiatives are planned or were already established. Methane emission measurement on biogas plants in Germany, Austria, Switzerland and Sweden are performed and a cost-benefit analysis for the several mitigation measures is calculated to give an indication of the financial impact of a particular measure. In addition, the knowledge about methane emissions from biogas plants is transferred to stakeholders and plant operators to sustainably reduce methane emissions. This is done by workshops (national and Europe-wide), webinars and information documents.

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