METHODOLOGY TO ASSESS METHANE LEAKAGE FROM AD PLANTS

Peer review and recommendations

Background and purpose of the response

In 2016 the Department of Business, Energy and Industrial Strategy (BEIS) commissioned Ricardo Energy & Environment to develop a methodology for monitoring methane leakage from anaerobic digestion (AD) plants. On completion of this report, BEIS requested peer review of this work in order to inform decision-making on the application of the methodology going forward. The peer review was commissioned to several internal and external experts and concluded in October 2018. The external experts have a track record of publication of peer-reviewed papers on the measurement and modelling of trace gas concentrations in the atmosphere. These peer reviewers are independent of both BEIS and Ricardo Energy & Environment. Internal experts are a group of climate scientist and engineers from the Science and Innovation for Climate and Energy Directorate in BEIS which are responsible for providing scientific and technical advice to policymakers in the Department.

The findings of these experts raised a series of weaknesses in the proposed methodology and a set of recommendations for improvements that are summarised in this document. The government recognises the knowledge generated by Ricardo Energy & Environment work and its usefulness to inform BEIS policies. However, with the aim of providing transparency in government decision-making and ensure the maximum rigour and scientific standards when informing policy, this document is published alongside the procured methodology report.

Peer review findings

Background environmental conditions and meteorological determinations

Determination and quantification of any environmental impact require a previous determination of the background conditions, which are those present prior the potential impacting activity starts. This is the only option for providing a fair evaluation of the environmental impacts derived from any industrial activity. The best practice to determine the background conditions is to establish an environmental baseline which is defined by different factors depending on the impacts that are going to be evaluated. In this case, the baseline concentration of methane in air needs to be determined. But there are other meteorological parameters, like predominant wind direction, that can affect the methodology and that need to be carefully determined. Robust determination of these parameters requires sufficient periods of monitoring prior to the industrial activity starts to ensure they are accurately determined. A minimum of one year of monitoring is commonly suggested for capturing appropriately the diurnal, weekly, and seasonal patterns and determining other activities taking place close to the monitored site that can modify the baseline.

Other meteorological factors like boundary layer height and boundary layer mixing parameters such as surface heat flux or surface roughness are also important to understand the mixing between source and receptor. These factors have not been accounted for sufficiently in the methodology and can affect the results derived.

Recommendations:

- Long-term monitoring prior AD activities start with the aim of establishing a robust environmental baseline of methane concentration and preferential wind direction.
- Determination of more meteorological factors to increase understanding of the mixing between source and receptor.

Sampling methodology and instrument layout

The reliability of the results derived from the model will strongly depend in a robust sampling methodology and instrument layout. However, the approach proposed in the report presents some weaknesses that could affect the results provided by the model.

1. Wind speed: the proposed approach to discard data when wind speeds are low, risks discarding of useful data inadvertently. It should be considered that under

different operational conditions data will be of variable quality and the key is to correctly define the uncertainty of each data.

2. Instrument layout:
    - Displaying the methane concentration detectors considering only the prevailing wind direction will invalidate sampling when wind direction differs. In these occasions, the sampling equipment will not be aligned with the wind direction. More sampling points distributed around the plant are needed with the objective of capture during times where wind direction differs from the preferential. This will have an impact on monitoring costs, but the results derived from the model will be much more robust and reliable. The results will be captured for more extended periods of time.
    - Sampling height is critical for characterising the plume of any emission. Measurement at a single height will might be insufficient to correctly characterise the plume, although it is recognised that sampling at several heights will result in higher costs. This is also very important for meteorological measurements since measuring at one height is insufficient to capture all the information needed. Measurements at multiple heights would allow better assessment of atmospheric mixing and local influences on mixing.
    - The distance from source point is another key factor that needs careful evaluation for correctly account for plume mixing in all conditions. The methodology described in the report recognises that this is an issue but does not provide an assessment of how to correctly determine the appropriate distance. This is a challenge that needs to be assessed on a case by case basis since it depends on factors that are varying often (like meteorological conditions) and other factors which are less variable (AD plant layout and surroundings).

3. Sampling frequency: there are no references to the sampling frequency in the report. Occasional punctual emissions are one of the big challenges of methane monitoring in AD plants. Sampling frequency plays a critical role in detecting these emissions. However, there should be a trade-off between excessively frequent sampling (which will result in higher costs and shorter lifetime of the equipment) and infrequent sampling (which will result in emissions not captures or not properly characterised). This is a point that should be assessed to determine an optimum sampling frequency.

4. Statistics: the relevance of the results depends on their significance and this can only be evaluated if the uncertainty of the results is known. The report assesses this challenge for the measurements. However, the uncertainty of the measurements is brought forward in the modelling. Therefore, the results derived from the model and their uncertainty are affected by the uncertainty of the measurements. This is not

considered in the report and needs careful assessment for deriving relevant conclusions from the results of the model.

5. Quality assurance and control: good QA / QC protocols are needed for assuring the relevance of the results and the conclusions derived from them. This has to cover all aspects related to measurement and data provision: plant operational regimes, maintenance of the equipment on-site (taking into account sensitivity against ambient conditions like temperature, pressure or humidity) calibration, drift correction, management of outliers or interferences with other species (for example methane determination using IR can present interferences from other hydrocarbons like volatile organic compounds which can be present in AD plants).

Recommendations:

- Define detailed protocols for data gathering and evaluation, allowing to determine the uncertainty of the results.
- Develop a robust methodology to define a correct instrument layout, taking into consideration that this will be highly affected by different factors which need to be assessed on a case by case basis.
- Establish solid QA/QC protocols for ensuring that the conclusions drawn for the results are relevant and representative of the emissions for the monitored plant.

Modelling

The model developed in this work is based on the following equation:

$$E = (C_d - C_u) \times A \times V \times 0.001$$

Where:

E = emission rate, gs^{-1}
Cd = Downwind concentration, mgm^{-3}
Cu = Upwind concentration, mgm^{-3}
V = wind speed, ms^{-1}
A = area of box, m^2

The application of this formula implies to consider that emissions are uniformly mixed to a height (which is not specified in the report) and a length (which is not specified but it is assumed as site width). The product of this length and this height is the area A used in the equation. However, there are some factors that can affect the validity of this assumption and that need further consideration:

1. A source further away from the point at which concentrations are monitored will mix to a greater height and vice versa for a close source. This will lead to a non-uniform

vertical concentration. Elevated or buoyant releases will have a greater effect on these issues. In addition, similar situations can apply to the horizontal length of A.

2. The height of A is extremely difficult to estimate and will vary from hour to hour. Estimating this from the wind speed only at one height is uncertain.

3. The concentration of the inflow to the site up to the height of A and along the length of A is assumed known and uniform from the upwind observation, which is not necessarily true. This is a source of uncertainty that needs to be accounted for.

4. Considering the wind speed is uniform vertically up to the height of A is a big assumption and depends on what the height of A is. It will be necessary to take into consideration vertical mixing, which is estimated in other models (such as ADMS or AERMOD).

Recommendation: there is a need to further develop this model to consider all these factors and decrease the uncertainty of the results derived from the model.

Pilot study

The idea of the pilot study is to assess whether the methodology is valid and can be extended to other AD plants for determining methane emissions. However, one short pilot study is not enough to completely validate a methodology and more case studies should be carried out. Strong case studies should be designed to derive relevant conclusions. For this reason, we are summarizing here some modifications in certain practices applied in this first pilot study that should be considered along with the recommendations about the methodology given in previous sections. Regarding instrument layout (distance to source and height) the report caveats that "*For future measurements it is suggested that the height and location of the sample points be adjusted according to the height of the emission points, especially if the boundary fence restricts the distance downwind of the AD plant*". However, we consider it is important to address this and other challenges here in more detail.

1. Sampling height: the sampling points were placed at a height of 1m which may be too low, especially for determining methane emissions which will rapidly rise due to buoyancy. For example, in the case of flare emissions or fugitive emissions from the top of a digester or a storage tank, it will be very unlikely that the sensors will be able to detect them.

2. Detectors: same type and model of detector should be used upwind and downwind. Otherwise, it is not possible to determine whether the differences in methane concentration detected upwind and downwind are a consequence of methane

emissions or a consequence different performance of the detection devices. In addition, the selection of appropriate detectors is highly important.

3. Instrumentation layout: the location of the different detector and measuring equipment should be reported in detail. For example, scales in the planes can be very useful to accurately determine distances to a source of emissions or to potential obstacles in the plant. This can help the evaluation and interpretation of the results.

4. Environmental baseline: a long-term monitoring for establishing the environmental baseline was not carried out prior to the plant activity started. For this case study, this was not an option since the plant was already in operation when the study was commissioned. However, this is something that should be taken into account for future studies that should consider projects in the early stages of their development instead of operative plants.
   In this case study, a commonly accepted methane concentration of 1-2 ppm has been considered as background. Whereas methane concentrations of 2 ppm can be a sensible assumption for clean air locations, it can also lead to wrong conclusions in highly industrialised areas or areas where other natural emitting sources are placed nearby. Regarding wind direction, the determination of the preferential wind direction has been done in a short period of time. This can be even more problematic than in the case of methane concentration in air due to the high variability of wind direction and the impact on the results can be higher since a wrong location of the sampling points (which is based on preferential wind direction) can invalidate the data collected.

5. Data gathering and evaluation of the results: the pilot study only lasted four days, but sampling durations of a year are discussed in the report. Taking into account the variability of factors such as operational regimes, environmental conditions or activities surrounding the AD plant, it is recommended to develop more efficient methods of compiling, processing, analysing/interpreting and displaying the data. For data collection, it seems sensible to monitor on a 24-hour basis over several months in different seasons for accurately characterise site emissions. This will help to identify periodic patterns or the influence from other activities that could influence the results derived from the monitoring and lead to the allocation of methane emissions to incorrect sources.

6. QA/QC protocols should be implemented and reported to avoid results that can be surprising or difficult to justify and to facilitate interpretation. In this case, there are some measurements recording methane concentrations as low as 1 ppm. However, it is known that background methane concentrations in the cleanest air (measured at the coast when prevailing onshore winds are blowing) are higher than this value. Therefore, so low measurements at an onshore site can be questionable. Similarly,

very low concentrations of methane (0 – 2.0 ppm) were being measured only a few metres away from very high sources of methane production (>400ppm). However, as there is a lack of information on how long measurements were taken for it is hard to discern what this means.

Recommendations for future pilot studies:

- Sample at more than one height to characterise vertical mixing and detect buoyant emissions.
- Use the same type of detectors upwind and downwind to avoid discrepancies due to different analytical techniques.
- Detailed reporting of instrument layout for facilitating the evaluation and interpretation of the results.
- Extended monitoring campaigns to capture variability due to operational regimes or changing meteorological conditions.
- Considered projects on the early stages of development to capture environmental baseline prior to the initiation of the operation of the plant.
- Define QA/QC protocols and report detailed sampling protocols to assess data quality and relevance of the conclusions drawn from the study.

Conclusions

The determination of methane emissions from AD plants is a key priority for quantifying the potential GHG savings delivered by this technology. This determination is still a challenge and a robust methodology needs to be developed for accurately measuring methane emissions from AD plants and obtaining relevant conclusions of their GHG abatement capability. The government commissioned a study with Ricardo Energy & Environment with this purpose which has set the basis for this methodology. However, our opinion is that this methodology is still insufficient to produce accurate results that could be used to estimate accurately the emissions from AD plants. The influence of factors like the environmental baseline, meteorological conditions or surrounding activities should be considered more precisely for the definition of the instrument layout and data analysis. The use of modelling tools is a powerful option for improving the quality of the results obtained from the monitoring, but the model described in this study needs further development to capture properly the influence of the meteorological conditions and to include the evaluation of the uncertainty in the results. In addition, robust sampling methodologies, QA/QC protocols and reporting practices need to be used for drawing significant conclusions.