Towards demand-driven Biogas plants:

Real-time determination of biogas quality

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Introduction

Biogas is the only renewable energy source with the possibility for on-demand production [1] and consequently it is set to become an even more important pillar in a future, sustainable energy landscape. Currently available technologies for flexible usage of biogas plant outputs mostly rely on cost-intensive use of gas storage tanks. Due to their limited volume, they are unable to cope with gas surpluses for more than a couple of hours. One appealing possibility to enable on-demand supply of biogas is to control the output itself. To facilitate this we propose an online monitoring technology to gauge the biogas quality.

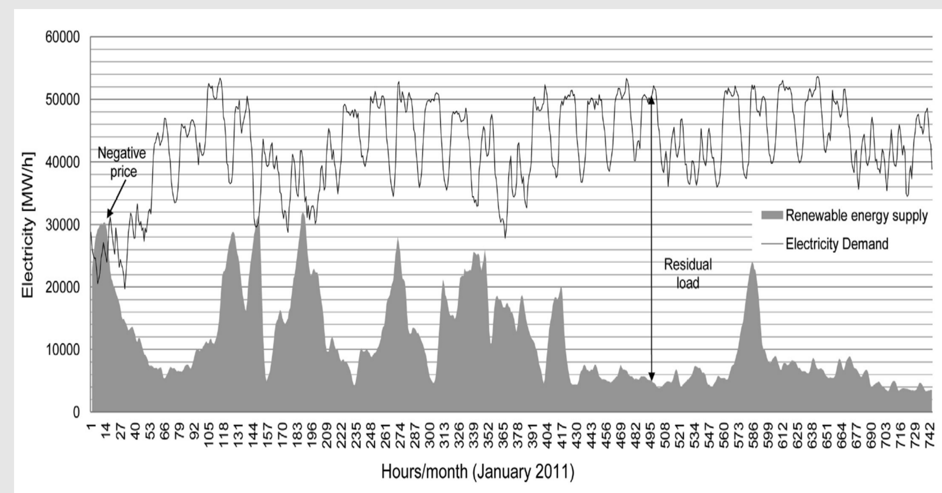
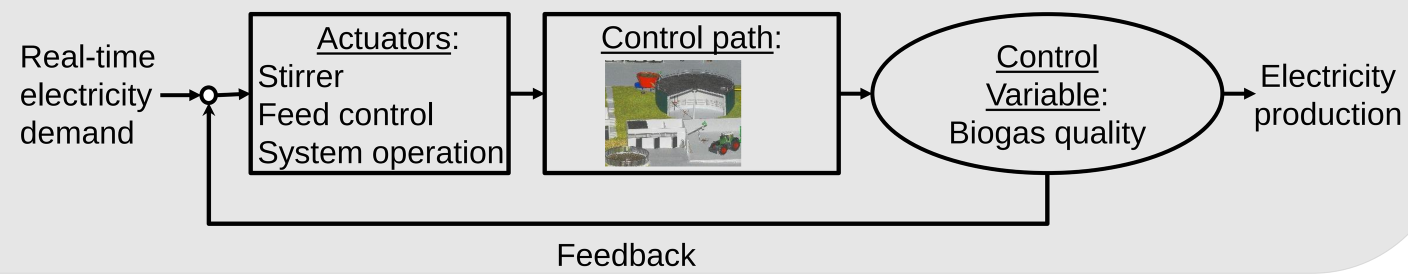


Figure 1: Currently, renewable electricity production is mostly anti-correlated with demand. Biogas plant actuators may enable a flexible production of biogas. Top figure from [2].



Miniature, in-situ gas analyzers

To allow for highly specific and sensitive detection of carbon dioxide (CO_2) [3] and methane (CH_4) [4] we employ a LED-based, non-dispersive infrared spectroscopy approach, where we use a photoacoustic (PA) detector [5] to gauge the light intensity. This way, our design is small, low-power consuming and without cross-sensitivities to water vapor.

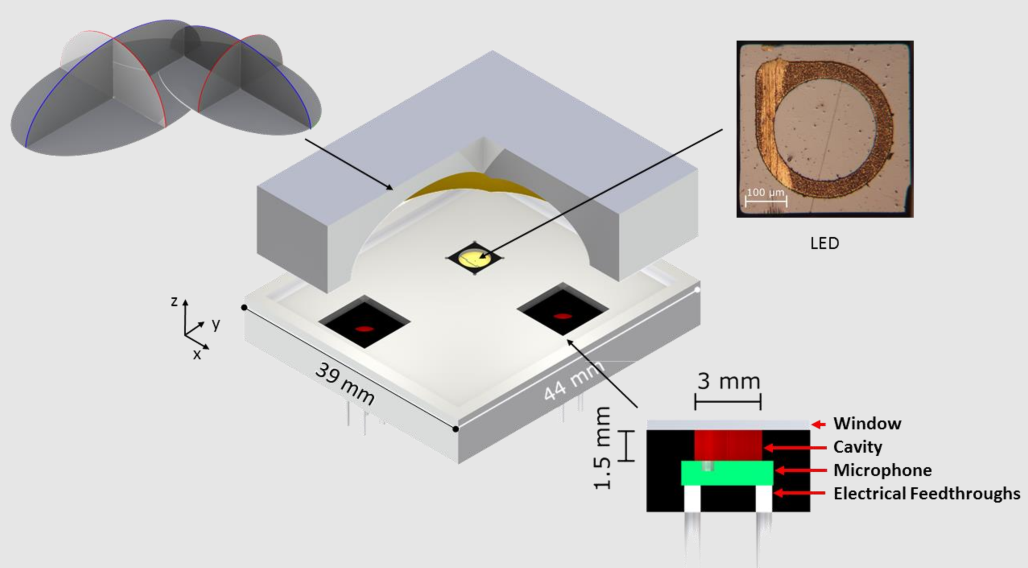


Figure 2: Schematic setup of the NDIR sensors employing PAS detectors and featuring a reference channel for long-term stable operation without the need for re-calibration.

This enables the measurement of these gases with high temporal resolution of a few seconds. Because we use low-power consuming light emitting diodes (LEDs) instead of the usually employed thermal emitter [6] as a light source, it is possible to operate the sensors intrinsically safe, which in turn allows for low-cost packaging as compared to explosion proof enclosures. Hence, it becomes possible to monitor the process online and at low overall cost, which consequently may lead to a widespread use of the technology.

Laboratory characterization

Prior to field testing the performance of sensor modules has been tested in a laboratory setting. Therefore, calibrated test gases have been applied using a custom build apparatus to simulate real-world situations in the lab [7]

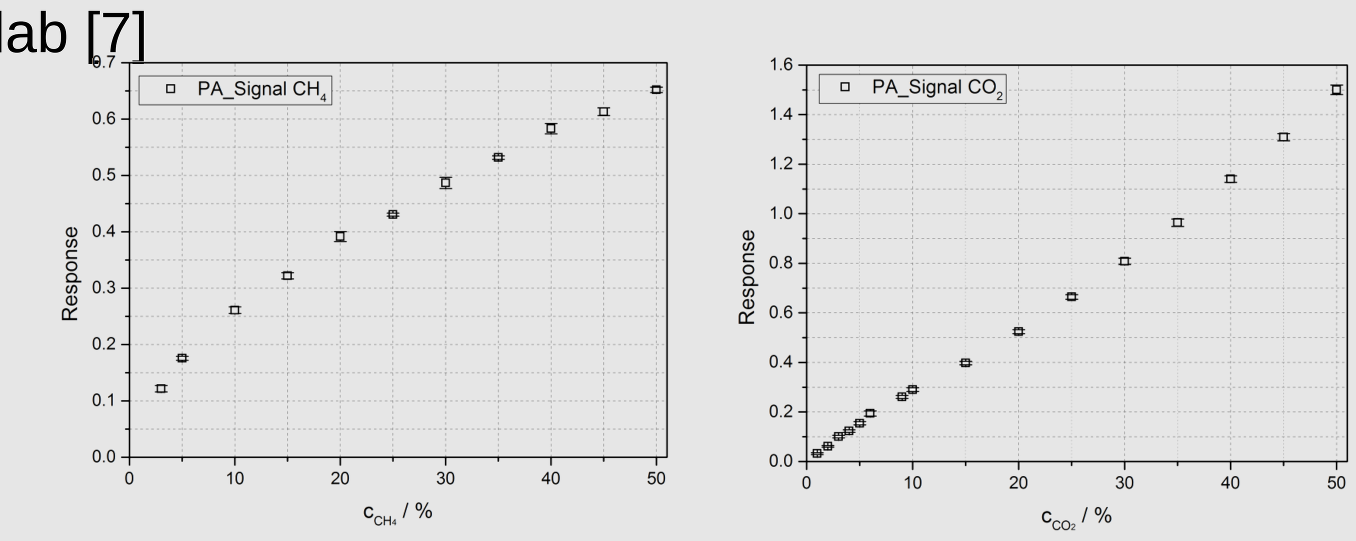


Figure 3: Laboratory test of the functionalities of the sensor modules for CO_2 and CH_4, respectively.

Benchmarking in the field

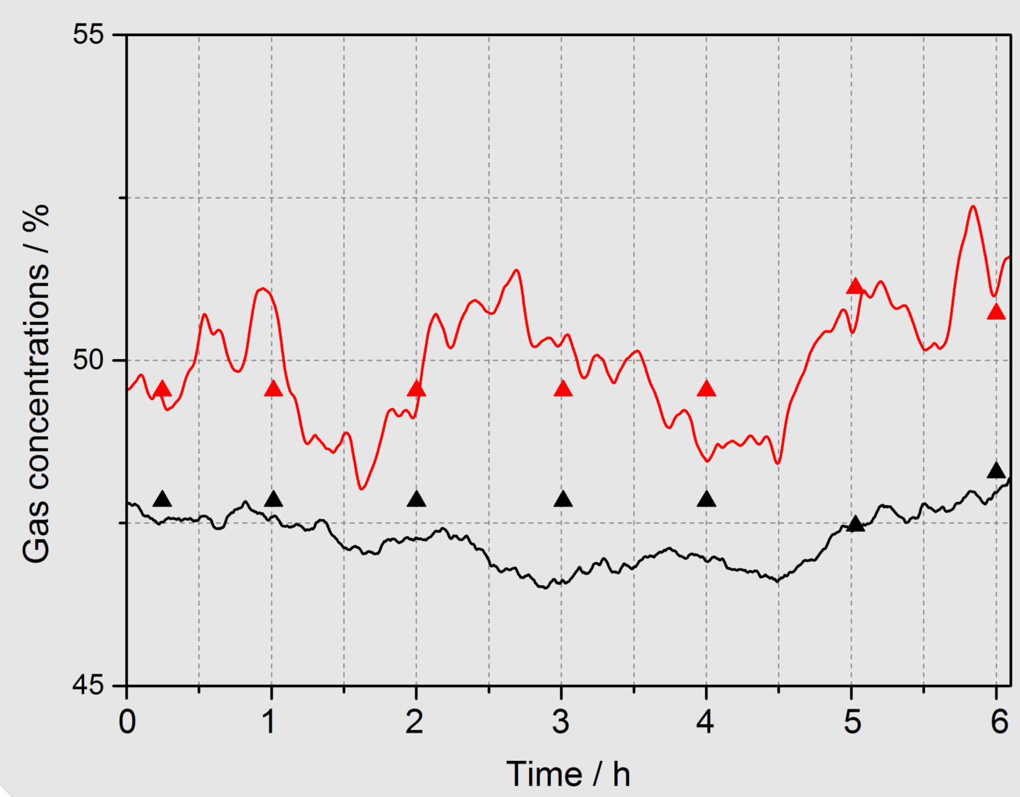


Figure 4: A first field test reveals rich dynamic behavior of the biogas reactor that may not be observed with current state of the art sensor systems. This kind of information may form the basis for active control of the methane yield.

Conclusion

In conclusion, we present a novel NDIR-setup based on a non-resonant photoacoustic detector technology, which shows significantly faster response to the probe gases than solid-state detectors but without the typically occurring cross-sensitivities towards humidity. Because of this, it is possible to build low-cost sensor systems for monitoring anaerobic digestion plants with small footprint, high sensitivity and high temporal resolution. Based on this information, the processes inside biogas plants can be monitored in real-time and thus enable a number of new possibilities for control of the processes.

References

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