Markus Schlattmann, Mathias Effenberger and Andreas Gronauer, Freising

Exhaust emissions from biogas fuelled heat/power plants

Emissions from heat/power plants powered by engines fuelled by agriculturally produced biogas (BBHKW) were investigated. The emission thresholds under the German regulations known as TA Luft (GTAL) could not be completely obeyed with any engine. The limit for plants with ≥ 1 MW capacity could, according to the authority figures, also be applied for the certification of smaller plants. For these, practically-oriented emission limits can be observed. Optimum engine settings and regular servicing can greatly sink reduce emission potential.

Dipl.-Ing. agr. Markus Schlattmann and Dipl.-In. Mathias Effenberger are members of the scientific staff in the Department of Environmental Technology in Land Use at the Bavarian State Institute for Agricultural Engineering (director: Dr. agr. Andreas Gronauer), Am Staudengarten 3, 85354 Freising; e-mail: schlattmann@ tec.agrar. tu-muenchen.de
The work was financed by the BstMLuU and factually accompanied by the Bavarian State Institute for Environment Protection

A refereed paper for LANDTECHNIK, the full-length version of which can be accessed under LANDTECHNIK-NET.com

Keywords

Exhaust gases, emissions, biogas, combined heat and power plant

The use of regenerative energies is becoming increasingly important in the light of the foreseeable exhaustion of fossil energy reserves and the problems with greenhouse gases. The efforts to find alternatives to fossil fuels have been increased in recent years. An alternative is the use of biogas in combined heat/power plants (BBHKW). These plants represent a broad range of capacities from a few kW to several hundred kW [1]. The possibility of matching performance to requirements creates the basis for an expansion of decentral energy production. In Bavaria a clearly growing number of plant constructions and extensions can be observed [2]. In this context, however, exhaust gases produced through burning of biogases in the engines are becoming increasingly important.

Legal conditions

Legislation for limiting these exhaust emissions is contained in the Federal Pollution Protection Act (FPPA) and the so-called TA Luft (GTAL). Concrete emission limitations in the renewed GTAL [3] are given in *table 3*. These values apply for plants of under 3 MW capacity and are based on a 5% covering oxygen content. Here, the GTAL serves as administration regulation for the FPPA.

A farm biogas plant, is liable to certification according to the FPPA where among other aspects, there is a production capacity from 1 MW, 2500 m³ storage volume or a throughput of more than 10 t per day of „waste requiring no special monitoring“ [4]. These plants are required to obey the GTAL limits. However also plants which are not liable to FPPA certification have to meet certain technical requirements [1]. Thus the GTAL can be applied by the authorities when deciding on certification of a farm biogas plant.

Target

There is the question if the given standards can be at all met. With biogas fuelled small plants it is not permitted to fail these standards but in practice the terms between measurements means that permission is neither given nor withheld. Thus with this investigation the question in the foreground is „what are the meaningful standards for BBHKWs in terms of emissions of carbon monoxide, nitrogen oxide and sulphur dioxide and how these can be classified in terms of the new GTAL?“

Measurement plan and objects

To get a long-term overview of emissions from the trial BBHKWs a measurement was

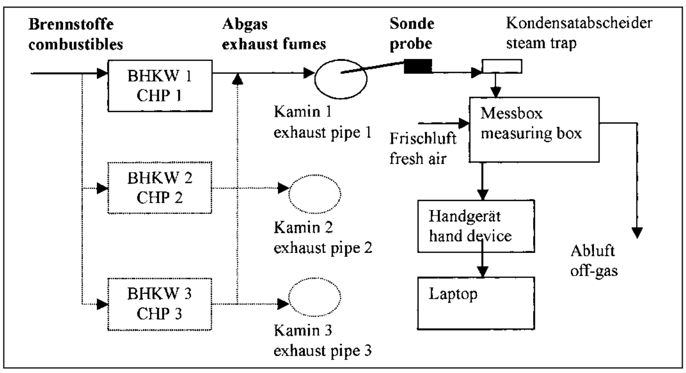

Fig. 1: Schematic overview of measuring setup

Table 1: Limiting values according to TA Luft (recommendation of Bavarian Environmental Protection Agency in brackets) for low power combustion engines

Engine type	Carbon monoxide CO [g m^{-3}]	Nitrogen oxide NO_x as NO_2 [g m^{-3}]	Sulphur dioxide SO_2 [g m^{-3}]
Zündstrahl	2,0 (2,0)	1,0 (1,5)	0,35 (0,35)
Otto	1,0 (1,0)	0,50 (0,50)	0,35 (0,35)

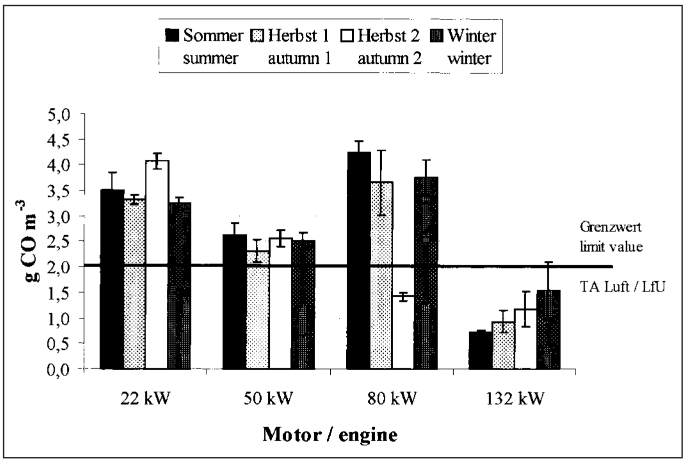

Fig. 2: Mean carbon monoxide emissions of the investigated engines (with standard deviations of the CO-emissions during each measuring period)

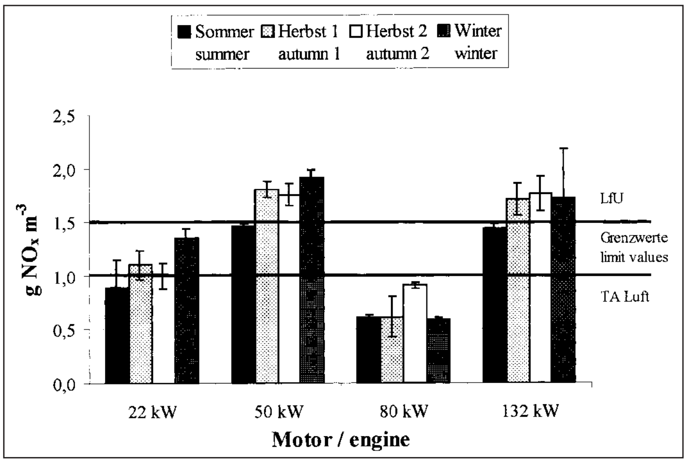

Fig. 3: Mean nitric oxide emissions of the investigated engines (with standard deviations of the NOx-emissions during each measuring period)

Table 2: Investigated engines in power classes

Power [$kW_{el.}$]	Cylinder-number	Capacity [l]	Repr. performance class [$kW_{el.}$]
22	3	2,9	<34
50	4	4,6	34-66
80	6	6,0	67-99
132	6	12,0	>99

carried out in each case in summer and in winter with two in the conversion periods. The exhaust gas tests were with the mobile TESTO 350 on four zündstrahler engines of different power ratings. Each test series covered five to seven individual measurements per engine. Alongside other exhaust parameters CO, NO_x and SO_2 were tested for. The engines tested were selected according to the results of a survey of Bavarian biogas plant operators (*table 2*). The measurements concentrated on zündstrahlers because these are commoner in practice [2]. Additionally these engines show a less satisfactory exhaust emission performance. The exhaust gases produced were measured in a chimney. A schematic overview of the recording is given in *figure 1*. The measurement data was standardised according to the GTALs 5% oxygen content ruling.

Results

Average CO emissions in a test series reached values of 0.7 g /m^3 with the largest engine up to over 4.2 g/m^3 in extreme cases with part-load running *(fig. 2*). NO_x emissions averaged 0.6 to 1.9 g/m^3 contrary to the CO emission of the respective engines (*fig. 3*). No significant emissions of SO_2 could be shown by the measurement equipment (measurement range 0 to 5000 ppm, precision < 5 ppm with values under 100 ppm). In total average, the SO_2 emissions were highest with 50 $kW_{el.}$- engines at 0.04 g/m^3 and with that lay well under the GTAL requirement of 0.35 g/m^3. The measurements indicated that with rising engine size the trend was towards a reduction in CO emissions. This trend appears to be broken by the 80 $kW_{el.}$ engine (*fig. 2*) but, except in test series 3, this engine was only running under part-load and showed in other test series, because of the incomplete burning of fuel and low burning temperatures, relatively high CO and relatively low NO_x values in exhaust gases. The measurements also showed that individual engine settings and servicing had an influence on emission performance. A systematic seasonal or outdoor temperature influence on the exhaust values was not recognisable and this could be because engine intake air generally came from the already-warm engine room interiors.

Classification of results

The trails confirmed the assumption that GTAL thresholds were not completely kept on existing small zündstrahl-engined plants subject to certification. Thus in the light of the current technical standard of small plant certification systems according to the certification authorities the GTAL should not be applied in favour of a target for encouraging of environmentally friendly energy production with practical limitations for exhaust emissions – as already recommended by the LfU [5] applied instead. In that varying conditions (procedural progress and thus gas quality, engine setting, servicing condition) influence engine emissions in practice, more frequent measurements might be required to be able to evaluate accurately enough the emission behaviour of a BBHKW with regard to correct engine setting. As the static tests have further shown, a significant difference between the exhaust values of different engines exists whereby a tendency to lower emissions by larger engines can be recognised. The current trend towards BBHKW modules of higher ratings [2] can be evaluated as positive therefore. Regular and skilled servicing of the engines which in practice up until now is hardly ever carried out could also help towards keeping within emission limits.

Literature

Books are identified by •

[1] • *Schulz, H. und B. Eder*: Biogas-Praxis. Grundlagen, Planung, Anlagenbau, Beispiele. 2. überarbeitete Auflage. Ökobuch-Verlag, Freiburg bei Staufen, 2001

[2] *Gronauer, A., M. Effenberger, F. Kaiser und M. Schlattmann*: Biogasanlagen-Monitoring und Emissionsverhalten von Biogas-Blockheizkraftwerken. Abschlussbericht. Bayerische Landesanstalt für Landtechnik. Abteilung Umwelttechnik der Landnutzung, 2002

[3] Anonymus: Kabinettsbeschluss vom 12. Dezember 2001 zur Novellierung der Technischen Anleitung zur Reinhaltung der Luft. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit [http://www.bmu.de], 2001

[4] N.N.: Genehmigungsverfahren für Biogasanlagen. Biogas-Journal (2002), H. 1, S.38-39

[5] *Reitberger, F. und B. Zell*: Biogasanlagen mit Verbrennungsmotoren < 1 MW Feuerungswärmeleistung – Anforderungen zur Luftreinhaltung. Bayerisches Landesamt für Umweltschutz, 2002