EFFICIENCY AND EMISSION OF CROP RESIDUES COMBUSTION FACILITIES IN SERBIA – STATUS AND NEEDED MEASURES FOR IMPROVEMENT

by

Milan MARTINOV, Miloš TEŠIĆ, and Miladin BRKIĆ

Original scientific paper
UDC: 662.636/.638
BIBLID: 0354-9836, *10* (2006), Suppl., 4, 189-194

Use of crop residues as fuel has a long tradition in rural areas of Serbia. Numerous biomass-fueled facilities were built during the 80s. Among those were small facilities for household heating, with thermal power from 5 to 50 kW, medium-size facilities for farm and greenhouses, with thermal power 50 to 1000 kW, and large facilities for processing of agricultural products, with thermal powers higher than 1000 kW.
The results showed that the level of biomass combustion facilities is in general very low. This is especially the case for heating facilities used for household heating. The measures for improvement were proposed.

Key words: *biomass, efficiency, emission, legislation*

Introduction

Use of crop residues as a fuel has a long tradition in Serbia, especially in typical agricultural region Vojvodina. Traditional stoves are still used, original or redesigned. Newly are used diverse small boilers, industrial products or self made. Based on authors experience was setup hypothesis that the efficiency of them is still very low, and emission of pollutants high.

Intensive contemporary use of solid biomass – crop residues, as renewable energy source, began in the province of Vojvodina in 1981, after energy crises. First facilities were imported and used for heating of workshops at large agricultural farms. In the mid 80s first domestic designs for thermal plants for combustion of straw, corn cobs, and sunflower straw and processing residues were developed and constructed. There are two basic types of thermal plants in use: with batch-fired and continuous feeding of the combustion chamber. Measurements have shown that most thermal plants have low energy efficiency, followed by high level of pollutants' emission [1-3]. That causes financial losses and is harmful for environment. Legislation and technical guidelines for minimal value of energy efficiency and permitted emission of the polluters are missing. Direct application of the legislations from developed countries can cause high additional expenses of production and result in decreasing application of biomass as an alternative fuel. Following the world trend in development, and having in mind domestic difficulties with the insufficient amount of energy, it is necessary to make the utilization of biomass widely spread.

Objectives

The main objective of the investigation was to review the status of biomass facilities, stoves, and boilers, concerning: general technical level, efficiency, and emission of pollutants. Further objective was to define the needed improvement in measuring. That applies to small facilities for household heating, with thermal power from 5 to 50 kW and also medium facilities for farms and district heating, with power higher than 50 kW.

Materials and methods

There were two groups of activities:

(1) Analyzing of small scale crop residues heating facilities and assessing their efficiency and emission characteristics based on technical solutions' applied – survey.

(2) Testing biomass stoves and boilers following the standard procedures.

The survey of heating stoves and small boilers was conducted on a typical Vojvodinian village. Twelve facilities were included, from traditional Pannonian stoves to hand-made boilers with thermal power from 5 to 50 kW. Technical level of facilities was evaluated. Only in few cases, measuring of exhaust gas temperature, containing CO and CO_2, as a base for efficiency and emission of pollutants was conducted. The tests were performed according to the official procedures: national standard JUS M.E2 203 [4], JUS M.E6.110 [5], and JUS M.R.4.020 [6], based on DIN 1942 (1979), and similar to ISO R889 [7]. For gas testing Testo 350 was used, and water flow was measured by Panametric PT 868-2. For temperature measuring thermal couples NiCr-Ni were used.

Results of testing and discussion

Survey

Stoves are stoked manually, mostly with corn cobs. Many stoves were built without professional supervision. Outdated technical solutions are vastly used because the investment value is smaller. Based on the reviewing of twelve small stoves, the following was concluded.

(1) Designs of stoves are outdated, in some stoves there are no grate, there is no control of combustion air, primary and secondary air supplies are not separated.

(2) In some of them the combustion, *i. e*. combustion air flow, is controlled by opening of ash-tray or combustion chamber door.

(3) The chimney designs are not adequate, concerning the dimensions and insulation.

Based on observed manifolds energy efficiency was assessed to be in the range 30 to 50%. The assessment of pollutants' emission was not possible without measuring, and can be only concluded that it is surely over defined upper limits.

The result of survey of biomass boilers showed similar results. All of them had very simple manual control of combustion air. Highest air control level was the use of Burdon's pipe. Energy efficiency was estimated to be 40-60%.

Among the advanced farmers was recorded high interest on biomass use, but the facilities have to be modernized, offering contemporary technical solutions and higher comfort.

Testing

Table 1 shows the results of testing for small and medium stoves with biomass combustion.

Table 1. Efficiency and emission of pollutants of biomass stoves, [1-3]

Producer/place/fuel	Power [kW]	η [%]	λ	CO_2 [%]	CO [ppm]	NO_x [mg/Nm^3]
Plamen 1, Niš – straw briquettes – straw–binder briquettes	 4 4	 38-77 26-70	 2.8-9.0 4.0-7.0	 1.2-3.0 1.3-2.7	 148-5588 1463-3115	 – –
Alfa plam, Vranje – maize cob briquettes	11	62-84	9.5-19	0.9-1.9	103-241 (in mg/Nm^3)	2.1-18.5
Roza, Vajska – straw briquettes	10 (20)	48 (70)	4.8-5.6	3.5-4.3	1000-5400	–
Hot air generator (pilot plant), Novi Sad – wood logs	53	68-74	2.4-2.5	8.0-9.2	4000-5000	–
Hot air generator (pilot plant), VINČA Institute, Belgrade – straw bales	557	–	2.6-4.7	6.3-10.5	0-820	–

η – energy efficiency, λ – coefficient of the excess air

From tab. 1 it is evident that there is a low degree of energy efficiency with the small and medium stoves, even though controlled stoking with packed biomass (straw briquettes, bales of straw, wood logs) was in question. The value of energy efficiency varies from 26 to 84% or in average 55%. The fundamental problem with these stoves is that there is no possibility of delicate regulation of combustion. Coefficient of the excess air is very high and varies from 2.6 to 19 or in average 10.8. This cools down the combustion chamber and causes poorer process of combustion, which decreases energy efficiency and increases the emission of harmful gases into the atmosphere. The amount of CO_2 is between 0.9 and 10.5% which is the result of high coefficient of the excess air rate. The amount of CO is up to 5,600 ppm, which is not too high for biomass combustion. N-oxides were measured in only one case, because in the process of biomass combustion its amount is very low as a result of low combustion temperature (600 to 750 °C).

From tab. 2 it is evident that there is a low level of efficiency with small and medium boilers on baled straw. It varies between 31 and 73% or in average 52%. A specific problem with the water heated boilers is that there is no possibility of delicate regulation of combustion. Coefficient of the excess air is very high and varies from 1.3 to 8.8 or in average 5.1. This results in poorer process of combustion, which decreases the energy efficiency and increases the emission of harmful gases into the atmosphere.

Table 2. Efficiency and emission of pollutants of straw bales boilers, [1-3]

Producer/ place	Nominal heating power [kW]	Measured power [kW]	η [%]	λ	CO_2 [%]	CO [mg/Nm^3]	NO_2 [mg/Nm^3]	VOC [mg/Nm^3]	Solid part [mg/Nm^3]
Bratstvo, Subotica	40	41.9	54	2.82 1.7-3.6	5.7-11.6	2280-5910	–	–	–
Šukom, Knjaževac	250	171-232	31-67	1.8-8.8	3.1-11.0	1560-9023	34-97	–	–
Bratstvo, Subotica	360	145-317	64-72	1.3-2.7	2.5-15.5	2.8 0-4.8 (in %)	–	–	–
Razvoj, Kula	400 500	249-369 340-685	63 66	2.1-4.8 1.5-5.9	3.1-15.3	2020-5230	21-36	–	–
Terming, Kula	500	59-170	50-73	1.34-3.5 4	5.5-14.4	4042-6403	1-7	–	–
Nigal, Novi Sad	750	299-530	43-69	2.8-7.9	2.4-6.5	1816-2814	1.7-2.43	180-573	4.7-28.1

η – energy efficiency, λ – air excess ratio

The amount of CO_2 varies between 2.5 and 15.3% which is a consequence of high excess air rate. The amount of CO is up to 9,023 ppm, which is high for biomass combustion. The content of organically tied carbon and solid particles in the smoke exhaust was measured only in one case. Results of the research show that the real values of the characteristics of thermal plants depend on several factors: type of bio-fuel, size of chipping, content of moisture, dosing biomass (manually, automatically or mechanically), type of combustion chamber, mode of providing air (with or without a ventilator), place of air inlet (beneath the grate and/or above the bio-fuel layer, parallel with the grate, *etc*.), air flow control in the process of combustion (with or without any kind of lip), the temperature of the combustion chamber, gas pressure in the chamber, the temperature of the exhaust gases in the chimney, amount of physically and chemically non-combusted bio-fuel, loss of thermal energy in the environment, *etc*.

Based on test results, survey of practice and experiences abroad the following values of efficiency of biomass combustion facilities have to be stated by low for period of next 6 years:

(1) Thermal power 5 to 50 kW, efficiency should be for stoves higher than 50%, and boilers higher than 60%.
(2) For boilers with power range 50 to 1000 kW efficiency should be over 65%.

After this period the EU standards have to be completely adopted.

Conclusions

Having in mind obtained results, following conclusions can be made.

National legislation on energy efficiency and emission of biomass energy facilities should reach European level, but step by step. The first next 6 years should be preparatory period with "milder" legislation – lower efficiency and higher emission limits. After this preparatory period full European legislative should be accepted as national.

The first step should be introduction of obligatory testing of biomass energy facilities concerning energy efficiency and emission of the pollutants. This should be done by authorized laboratories. Consequently, one or more national testing laboratories should be set up and adequately equipped.

It is necessary to continue the activities on improving technical solutions for the application of renewable solid biomass with the objective to accomplish high level of plant efficiency, lower emission and input of labor.

There is a need to create clear national policy on biomass use as energy, with adequate supporting measures.

Acknowledgment

This research has been financed by Ministry of Science and Environmental Protection, in the frame of National Energy Efficiency Program, studies No. 273-002 and 273-020, and project 608-1025 (Development program: Use of alternative and renewable energy resources). Research has also been supported by companies Termoplin, Smederevska Palanka, Nigal, Novi Sad, and Terming, Kula, Serbia.

References

[1] Brkić, M., Janić, T., Galić, S., Biomass and Gas-Fueled Boiler for Farm Heating and Incineration of Dead Animals and Confiscates, *Proceedings*, 9th International Congress on Mechanization and Energy in Agriculture and 27th International Conference of CIGRE, Section IV (The Efficient Use of Electricity and Renewable Energy Sources), Faculty of Agriculture, Izmir, Turkey, 2005, pp. 166-170

[2] Brkić, M., Konstantinović, M., Janić, T., Efficiency and Emission at Small Furnaces for Bio-Briquettes Combustion, *Proceedings on CD*, EE&AE'2004 International Conference, Rousse, Bulgaria, 2004, pp. 303-307

[3] Brkić, M., Gobor, Z., Janić, T., Efficiency and Emission of Biomass Thermal Plants in Yugoslavia, *Proceedings*, Conference of Union of Scientists – Rousse and CIGR, Section IV: Energy Efficiency and Agricultural Engineering, Rousse, Bulgaria, 2002, Vol. 2, pp. 106-113

[4] ***, JUS M.E2 203 – The Boiler's Facilities, Thermo-Technical Tests, Book of Rules No. 31-11074/1 (in Serbian), Yugoslav Official Gazette, No. 42, Belgrade, 1980

[5] ***, JUS M.E6. 110 – The Limit's Values of Emission Gases from Burner for Wood Logs, Wood Briquettes and Waste of Agricultural Materials for Thermal Power up to 1 MW (in Serbian), Federal Bureau of Standardization, Belgrade, 1987

[6] ***, JUS M.R.4.020. – The Limit's Values for Carbon Black Number (in Serbian), Federal Bureau of Standardization, Belgrade, 1987

[7] ***, ISO Recommendation R889, Test Code for Stationary Steam Generators of Power Station Type, VDI, Düsseldorf, Germany, 1968

Authors' addresses:

M. Martinov, M. Tešić
Faculty of Technical Sciences, University of Novi Sad
8, Trg Dositeja Obradovića, 21000 Novi Sad, Serbia

M. Brkić
Faculty of Agriculture, University of Novi Sad
8, Trg Dositeja Obradovića, 21000 Novi Sad, Serbia

Coresponding author (M. Martinov):
E-mail: mmartog@uns.ns.ac.yu

Paper submitted: November 5, 2006
Paper revised: December 11, 2006
Paper accepted: December 4, 2006