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Potentials, practice and prospects
of energy utilization of biomass in Serbia: gaseous biomass - BIOGAS

POTENTIALS, PRACTICE AND PROSPECTS OF ENERGY UTILIZATION OF BIOMASS IN SERBIA: GASEOUS BIOMASS- BIOGAS

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1. INTRODUCTION

By now, only few studies and assessments about potentials and impacts of biogas production in Serbian province of Vojvodina have been made, as in TESIC et al., 2007; MARTINOV & DJATKOV, 2008. Based on experiences of other countries, it is clearly known that energy produced from renewable energy sources (RES), and particularly from biogas, can be only exceptionally cheaper than from fossil fuels (MARTINOV & DJATKOV, 2008). Therefore state bodies, by introduction of proper legislation, should subsidize biogas production and its utilization in energy production. The legislation would be guaranteed feed-in tariffs for delivered electricity. Research and development (R&D) in the field of biogas technology should be supported as well, by dedicated funds, in order to facilitate further development of biogas technology in Serbia.

Serbia signed Memorandum of Understanding (EUROPEAN COMMISSION, 2002), wherewith obligations and goals to follow European RES policy have been accepted. The core of policy is defined in *"White Paper"* and two directives (EUROPEAN COMMISSION, 1997; EUROPEAN PARLIAMENT, 2001; EUROPEAN PARLIAMENT, 2004). Still, the most important legislation, which is proposed by the Serbian state bodies, i.e. regulation with defined feed-in tariffs for electricity produced from RES, should be implemented. The consequence is absolute nonexistence of biogas plants in Serbia.

The production and utilization of biogas from anaerobic digestion has many potential positive contributions, mainly to the: national economy, environmental protection and rural development. Additionally, benefit for the society is its utilization as renewable energy source, which would reduce dependence on limited fossil resources. Serbia is, as most European countries, strongly dependent on fossil energy imports. By developing and implementing renewable energy systems, such as biogas produced from national and regional biomass resources, it would increase security of national energy supply and diminish dependency on imported fuels.

On most farms in Serbia exists the problem of animal manure storage. The storage of manure is mostly in lagoons, which are uncovered and none-isolated to surrounding ground. By installation of biogas plants, emissions of carbon-dioxide (CO_2) by biogas utilization could be removed, as well as methane (CH_4) and nitrous oxide (N_2O) emissions by anaerobic digestion of animal manure and subsequently its application as a fertilizer. By reduction of these emissions, contribution to mitigation of global warming is achieved. Contamination of surrounding ground and persistent and unpleasant odors could be removed as well.

Contribution to the rural development and creation of new jobs by production of biogas would be achieved, while work power for production, collection and transport of feedstock for biogas production is needed. Additionally, there is a need for the manufacture of technical equipment, construction, operation and maintenance of biogas plants. For the producers of biogas, e.g. farmers, income from sold electricity and digested residue as a fertilizer, and savings in heat energy for heating or processing purposes are certainly significant benefits.

In order to utilize possible benefits from biogas production, Serbian potentials based on available feedstock should be firstly determined. Economic operation of biogas plants is almost always questionable, and in some cases even with the guaranteed feed-in tariffs. Therefore, only potentials with positive economic results should be considered. The economic efficiency is mostly influenced by the size of biogas plant, affordable feedstock, as well as ability to efficiently utilize produced (heat) energy.

2. Potentials

Potentials for biogas production in Serbia are estimated based on animal production (from pig and cattle manure) and potential usage of energy crops.

Manure from animal production

Estimation is given for medium (M) and large (L) farms, where is possible to achieve significant capacity and efficient production of biogas. Based on animal production, the amount of manure on these farms is estimated and therewith possible biogas production. Potential biogas production is calculated assuming that potential biogas yields from pig and cattle manure are 28 Nm^3/t and 25 Nm^3/t, with share of methane of 65% and 60%, respectively (BMELV, 2008). Needed electrical capacities of combined heat and power units (CHPUs) for utilization of produced biogas are calculated assuming that electrical efficiency is 37% (FAL, 2005). The case for pig breeding farms is presented in Table 1, while for cattle farms in Table 2.

Table 1: Production of liquid manure, potential biogas production and needed electrical capacities of CHPUs on pig breeding farms in Serbian municipalities

Municipality	No. of farms	Total yearly number of swine	Daily manure production, t/d	Daily biogas production, Nm^3/d	Needed capacity of CHPUs, kW_e
Sombor	9	35,600	327	9,156	990
Subotica	7	11,600	106	2,968	320
Senta	6	35,600	296	8,288	895
Backa Topola	4	10,800	100	2,800	302
Vrbas	12	101,000	929	26,012	2,809
Novi Sad	6	38,000	349	9,772	1,055
Kikinda	8	33,500	307	8,596	928
Zrenjanin	8	25,700	236	6,608	714
Vrsac	3	3,800	34	952	102
Pancevo	9	45,300	417	11,676	1,261
Kovin	4	7,400	67	1,876	202
Ruma	3	17,000	156	4,368	471
Sr. Mitrovica	6	29,500	271	7,588	819
Beograd	6	42,800	393	11,004	1188
Smederevo	2	8,600	79	2,212	238
Pozarevac	5	36,800	337	9,436	1,019
Sabac	2	3,400	31	868	94
Valjevo	1	5,200	48	1,344	145
Loznica	1	500	5	140	15
Krusevac	1	11,100	107	2,996	323
Jagodina	4	38,200	355	9,940	1,073
Nis	1	4,400	42	1,176	127
Zajecar	2	14,500	133	3,724	402
Leskovac	1	11,000	106	2,968	320
Prokuplje	1	13,000	119	3,332	358
Totally	112	584,300	5,350	149,800	16,170

Table 2: Production of liquid manure, potential biogas production and needed electrical capacities of CHPUs on cattle farms in counties of Serbia

County	No. of farms	No. of cattle units	Daily manure production, t/d	Daily biogas production, Nm^3/d	Needed capacity of CHPUs, kW_e
Backa- north	5	10,180	245	6,112	609
Banat- middle	4	3,150	76	1,892	188
Banat- north	3	9,670	232	5,806	578
Banat- south	5	8,290	199	4,976	496
Backa- west	7	5,820	140	3,496	348
Backa- south	4	14,770	354	8,864	883
Srem	2	7,020	168	4,216	420
Macva	2	5,660	136	3,400	339
Kolubara	3	15,600	375	9,366	934
Podunavlje	5	3,110	75	1,866	186
Branicevo	5	11,800	284	7,110	708
Sumadija	3	8,410	202	5,048	503
Pomoravlje	3	4,940	119	2,968	296
Bor	2	1,690	41	1,016	101
Zajecar	4	8,200	197	4,920	490
Zlatibor	2	3,020	72	1,812	180
Moravica	5	9,510	228	5,710	569
Raska	4	7,820	188	4,692	467
Rasina	4	8,000	192	4,804	479
Nisava	1	3,240	78	1,948	194
Toplica	1	1,170	28	705	71
Pirot	2	2,670	63	1,605	160
Jablanica	1	2,380	56	1,428	142
Pcinje	1	200	5	120	12
Belgrade city	3	8,630	207	5,180	517
Totally	78	164,950	3,960	99,060	9,870

Total potential biogas production on (M&L) pig breeding and cattle farms in Serbia is 90.8 mil Nm^3/a. Electrical capacity of 100 kW_e is defined as a minimum capacity of potential biogas plant, in order to facilitate economic production and utilization of biogas. Only 70 of total 112 pig farms and 65 of 78 cattle farms satisfy this condition. Concerning this, potential biogas production would be 82 mil Nm^3/a, and sum of CHPU needed electrical capacities is 21.7 MW_e.

Energy crops

The most important plants in crop farming, which could be used for biogas production, are maize and cereals (wheat, barley, rye). Whole-crop silage would be used. Maize is sown on 1,358.000 ha and cereals on about 940.000 ha. Their yields are presented in Table 3.
In order to estimate available potentials of energy crops for biogas production, it was distinguished between large (L) and small and medium (S/M) farms. Large farms have enough

arable land and are mostly dealing with animal production as well. In case of existence of biogas plant on these farms, which would use manure as a feedstock, it is possible to increase capacity of biogas production by co-digestion of energy crops.

Table 3: Yields of maize and cereals in Serbia

Crop	T[1]	Acreage, 1.000 ha	Large farms, 1.000 ha	S/M farms, 1.000 ha	Yield, 1.000 t		Whole crop yield, 1.000 t	
					Large farms	S/M farms	Large farms	S/M farms
Wheat	↓	797	178	619	703	2,122	1,646	4,668
Rye	–	8.6	0.8	7.8	1	13	2.2	28.6
Barley	–	135	46.6	88.4	151	279	332	615
Maize	↑	1,358	133	1,225	764	6,615	1,680	14,555
Totally					1,619	9,029	ca. 3,660	ca. 19,867
					10,648		23,527	

[1] Trends of growing surface; S/M: small and medium.

According to relations defined in MARTINOV & DJATKOV (2008), in Table 3 are presented whole crop yields for maize and cereals. For large farms, it is around 3.66 mil t/a. It is supposed that it would be possible to use about 5% of available amount, without serious impact on food production. Based on theoretical biogas yield from maize silage of 202 Nm^3/t and from cereals of 163 Nm^3/t (BMELV, 2008), potential biogas production would be around 33.1 mil Nm^3/a. Calculating average share of methane in produced biogas of 52% (BMELV, 2008) and electrical efficiency of 37% (FAL, 2005), needed electrical capacity of CHPUs is 7.2 MW_e.

Summarized potentials, forecast

In Table 4 are presented summarized potentials for biogas production and forecast for 2020. Installed electrical capacities are calculated based on needed electrical capacities and annual full load operating hours of CHPUs of 7,880, i.e. around 90% of their capacity utilization, where 10% is capacity reserve. In the future, the potential for biogas production could increase due to the increase in animal production on larger farms. The increase would be enabled through merging of individual producers and smaller farms and through transfer of capacity from smaller to larger farms, in order to fulfill technology requirements. For the potential of biogas production from energy crops there is no significant prospect for increase, since the food production would be affected.

Table 4: Summarized potentials for biogas production in Serbia and forecast for 2020.

Actual potentials			
Feedstock	Potential biogas production, mil Nm^3/a	Potential electricity production, GWh_e/a	Needed (and installed) electrical capacities of CHPUs, MW_e
Manure	82.0	190.5	21.7 (24.1)
Energy crops	33.1	63.4	7.2 (8.0)
Sum	115.1	253.9	28.9 (32.1)
Forecast for 2020.			
Feedstock	Potential biogas production, mil Nm^3/a	Potential electricity production, GWh_e/a	Needed (and installed) electrical capacities of CHPUs, MW_e
Manure	98.4	228.7	26.1 (29.0)
Energy crops	33.1	63.4	7.2 (8.0)
Sum	131.5	292.1	33.3 (37.0)

3. Current practice, status

During the mid-eighties of the twentieth century, seven biogas plants were under construction in Serbia. Some of them were not completed, and some haven't seen so much as a year-long successful exploitation. Their economic justification was doubtful, since only heat energy was produced and utilized, without electricity (TESIC et al., 2007).

At sight, there are no biogas plants in Serbia and the main reason for their absolutely nonexistence is the lack of proper legislation and regulations, and absence of subsidized prices of electricity produced from renewable energies, i.e. feed-in tariffs. However, these documents are in preparation and are expected to be in affect until the end of 2009. According to draft version of the regulation of impetuses for privileged producers of electricity (The GOVERNMENT of REPUBLIC of SERBIA, 2008), maximum rate for electricity produced from biogas would be around 16 c€/kWh$_e$, and is dependent on installed electrical capacity. By increase of installed electrical capacity of biogas plant, the price per kWh$_e$ of electricity delivered to the net is decreasing (*16.444-2.222*P; P- installed electrical capacity in MW$_e$*). Therefore, a biogas plant with capacity of 300 kW$_e$ would have feed-in tariff of 15.77 c€/kWh$_e$.

4. Visions and prospectus

Potentials of biogas production are presented for animal manure and energy crops. Other resources, as organic wastes from the food, feed and pharmaceutical industry, catering waste, could be also used. Still, amount of these resources are mostly insufficient to provide significant capacity of biogas production, and may be used only as a supplement and only in the case if there is no other useful usage of this material. The source should be in the direct vicinity of biogas plant, in order reduce time and high costs for transportation (AL SEADI et al., 2008). Based on these facts, the usage of this sort of feedstock would not significantly increase determined potentials presented in Table 4.

The costs for transportation can be even higher than the benefit brought by increase of biogas production by usage of materials which are distant from biogas plants. In the case of animal manure, which has significantly lower specific biogas yield comparing to other feedstock, and concretely around 7 times lower than maize silage (BMELV, 2008), it is feasible to pump it to short distances, but not to transport it.
Maize has higher yield than cereals and higher potential biogas yield, what makes higher potential energy production. Therefore, among energy crops, the usage of this crop for biogas production is preferable, and production on own land and near the biogas plant.

With the increase of power of biogas plant, specific investment per installed kW$_e$ decreases. It ranges between 3.000 and 2.000 €/kW$_e$ for plants between 100 and 350 kW$_e$, respectively, and under 2.000 €/kW$_e$ for biogas plants over 350 kW$_e$ (BMELV, 2008). Additionally, CHPU with higher capacity has higher efficiencies (electrical and thermal). Therefore, it is desirable to install biogas plants with as high capacity as possible, if there is a sufficient amount of feedstock to support biogas production. Still, with the increase of installed power, the rate of feed-in tariff decreases. On most farms in Serbia, it is possible to install biogas plant of maximum up to 300 kW$_e$ in the case when they use only manure from own farm, with needed investment of 600,000-750,000 €. For biogas plants with higher capacities, usage of energy crops would be needed.

In MARTINOV & DJATKOV (2008), economic appraisal of two biogas plants were made. The calculation showed that breakeven price of produced electricity (zero profitability) is 10.2 c€/kWh for the biogas plant on pig breeding farm. This farm would use cost-free pig manure as feedstock and utilize a significant amount of surplus heat energy. In rooms for breeding of pigs, heating season is extended and lasts 8 months. In the case of other biogas plant, breakeven price of produced electricity reached 18.6 c€/kWh, while it would use significant amount of maize silage for biogas production, with price of 27 €/t. Therefore, the usage of energy crops is expensive and can be economically justified only in specific cases. Based on calculations done, recommendation is that the feed-in tariffs should range from 11 to 16 c€/kWh, in order to facilitate payable production and utilization of biogas (MARTINOV & DJATKOV, 2008).

Biogas plants are mostly located out of residential areas, that causes the problem of utilization of heat energy. Energy demand for heating of digesters ranges 5.6-30% of produced amount (EFFENBERGER et al., 2008). The rest, i.e. surplus heat, is almost never entirely utilized and must be delivered to the surrounding air by the engine's coolers. Therefore, a continuous consumer of heat energy nearby biogas plant is desirable. It can be a greenhouse, drier, producer of cooling energy etc. Still, additional investment is required for the heating system pipeline or devices as driers and coolers. It is recommended that heat consumer should be located as close as possible from biogas plant and assessment should be made if this is economically justified (AL SEADI et al., 2008). Analyzing 10 representative biogas plants in Bavaria, surplus heat utilization ranged between 14.1% and 52.6% (EFFENBERGER et al., 2009), in cases where an external heat consumer exists. Based on the reached utilized amount in practice, it is to be expected that maximum value of utilization of the surplus heat could be around 60%.

After taking an effect of appropriate legislation, it is estimated that 5-10 biogas plants would be installed in next 5 years on the most potentially suitable locations- pig breeding farms with additional nearby heat consumers. Total installed electrical capacity would be up to 2 MW_e. On farms of this type, operation of biogas plants should be economically justified. These biogas plants could serve as pilot plants for further R&D of biogas technology in Serbia would increase totally installed capacity of biogas plants. In order to reach defined capacities of biogas production from animal manure of 21.7 MW_e (Table 4), particular farms should be individually analyzed and feasibility studies should be done. Therewith site-specific economic conditions of potential biogas plants would be known and biogas plants should be classified due to their type, feedstock they use, energy consume and production schemes. Based on classification, different rates for feed-in tariffs and stimulating bonuses should be defined, as it is practice in some countries (BMU, 2009; BUNDESMINISTERS für WIRTSCHAFT und ARBEIT, 2008), e.g. Germany, Austria, where biogas technology is already in longtime use. By now, defined feed-in tariffs in the Serbian draft version of regulation of impetuses for privileged producers of electricity, feed-in tariffs are only dependent on the size of plants (THE GOVERNMENT of REPUBLIC of SERBIA, 2008).
The electricity consumption in Serbia for 2008. was 26,650 GWh_e (Ministry of Mining and Energy of the Republic of Serbia, 2008). By reaching total potential capacity of biogas production in Serbia of 29 MW_e, 254 GWh_e/a of electricity would be produced, what makes around 1% of electricity consumption. Based on this, national energy supply could not rely on electricity from biogas, but important environmental problems could be solved. For achieving this potential capacity in biogas production, investment from 70-80 mil € would be needed.

In Serbia, due to the absence of biogas technology, there are no experts in this field. Therefore, potential managers, owners and users of potential biogas plants should pass process of education in order to successfully manage the operation and maintenance of their biogas plants. It is also necessary to establish dedicated funds and to cherish research groups on universities and research institutions, wherewith R&D in the field of biogas could be enabled. Cooperation with institutions from abroad, which possess experience and *"know-how"* of long standing, would be of great importance for further development of biogas technology in Serbia.

5. CONCLUSIONS

In Serbia, the biggest potential for biogas production is manure from animal production, and subsequently energy crops. Assessment showed that the totally possible annual production of electricity is significant, and could be around 254 GWh_e, with installed electrical capacities of CHPUs of around 32 MW_e. When using animal manure as a feedstock, only farms with significant capacities and possibility for efficient production of biogas were considered, and in the case of energy crops, potentials are defined as available amounts on large farms where is possible to increase biogas production based on animal manure and amounts that would not impact food production. In the future, by 2020, it is forecasted, that the potential for biogas production could increase due to the transfer of capacity to larger farms, in order to fulfill technology requirements. Potential biogas production from energy crops will not increase, since the food production would be affected. Potential electricity production from biogas in Serbia for 2020. would be around 292 GWh_e, with installed electrical capacities of CHPUs of 37 MW_e.

In Serbia, there are no biogas plants since technology, i.e. equipment, is expensive and therefore production should be subsidized. Barriers are lack of proper legislation and absence of feed-in tariffs. Still, these documents and mechanisms are in preparation. Based on assessment done for some potential biogas plants, it was recommended that feed-in tariffs should range 11-16 c€/kWh_e, and proposed rate of feed-in tariff in prepared documents would be around 16 c€/kWh_e. Therefore, the implementation of these tariffs is of the greatest importance for the economically justified production and utilization of biogas in Serbia. Basic feedstock for biogas production should be manure from animal production on farms. Energy crops and some waste materials could be used in very specific conditions, due to their high price or transport costs. When using energy crops, the most suitable is maize silage. The capacity of biogas plant in Serbia, which uses only manure from own farm would not overcome 300 kW_e.

The most suitable locations to install biogas plants are pig breeding farms, due to availability of cost-free feedstock for biogas production and high utilization of surplus heat. Additional nearby consumer of heat energy would improve or facilitate economic efficiency of biogas production. Biogas production by using of energy crops is not payable, even with proposed feed-in tariffs, and with potential biogas plants on cattle farms, there would be a problem of surplus heat utilization. It is estimated, that in next 5 years, after taking an effect of appropriate legislation, 5-10 biogas plants could be firstly installed on pig breeding farms, with totally installed electrical capacity around 2 MW_e. Further enlargement of capacities, in order to achieve estimated potentials from animal manure of 21.7 MW_e, may be attained with appropriate government support by means of establishing funds for R&D and continuous monitoring of requirements for economic production of biogas and undertaking needed actions.

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