CODEN STJSAO
ZX470/1465

ISSN 0562-1887
UDK 662.767.2:661.99:620.95

Biogas Potential in Croatian Farming Sector

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Keywords
Biogas
Cows
Forming sector
Manure
Pigs

Ključne riječi
Bioplin
Gnojivo
Krave
Stočarstvo
Svinje

Received (primljeno): 2009-11-20
Accepted (prihvaćeno): 2010-06-10

Original scientific paper

Farming sector, in general, is a big producer of manure and thereby also a big producer of greenhouse gasses. The issue of methane production from animals on farms should be seen as an opportunity in producing green energy and contributing into reducing green house effect. Croatian farming sector is pretty undeveloped if we compare it to the other EU member states. This is one of the legacies from past state where agriculture was not something worth of heavy investments. This was not only the case for Croatian farming sector, but also Croatian agriculture in general for the last twenty or more years. However in the last five years there were a lot of improvements and investments in agriculture and in the farming sector. More and more questions regarding energy issues and energy management on farms are becoming important. But this is still not enough if we want to use all of our resources and potentials. Especially if we consider the fact that there are no serious biogas plats in Croatia jet. All of this information with a promising increase in agricultural investing leads us to a question of total biogas potential for the farming sector in Croatia. Through this paper the total number of farms will be shown and their technical potential for producing, storing or using biogas. The special emphasis will be on two most promising farming sectors: cows and pigs. The main challenges would be to separate small family farms that basically have no biogas potential and bigger modern farms that could be considered for biogas production. The value of finding Croatia s biogas potential regarding farms is also important since farms are consuming a lot of energy in their everyday operations and part of that energy consumption can be compensated from renewable energy source like biogas.

Potencijal za proizvodnju bioplina na farmama u Hrvatskoj

Izvornoznanstveni članak

Kad govorimo o bioplinu i njegovoj produkciji, sektor stočarstva se nameće kao jedan od najizglednijih. Isto tako, zbog velike proizvodnje gnojiva, ali i samih enteričkih procesa ovaj sektor predstavlja značajan izvor staklenič kih plinova. Upravo proizvodnja bioplina predstavlja jedan od koraka smanjenja emisija staklenič kih plinova. Hrvatski stočarski sektor prilično kaska za onim europskim, što je posljedica sustavnog neulaganja, ne samo u sektor stočarstva, nego i sektor poljoprivrede generalno. U posljednjih par godina vidimo pomake u načinu ulaganja gdje se javljaju nove i moderne farme koje zadovoljavaju visoke standarde proizvodnje te se na njima može organizirati ekonomski isplativa proizvodnja električne i toplinske energije iz bioplina. Naravno sve to nije dovoljno kako bi Hrvatska iskoristila sve svoje potencijale, pogotovo ako se uzme u obzir da u Hrvatskoj još masovno nisu rasprostranjena bioplinska postrojenja. Upravo zbog toga, postavlja se pitanje koji je pravi tehnički potencijal u proizvodnji bioplina, odnosno topline i električne energije iz bioplina za sektor stočarstva u Hrvatskoj. Kroz ovaj rad predstavljena je metodologija izračuna samog potencijala koja je primjenjiva za svaku individualnu farmu te sami potencijali za obiteljska gospodarstva i velike farme. Sam izračun je napravljen za dva najisplativija sektora, a to su: govedarstvo i svinjogojstvo. Najveći izazov je prikupljanje kvalitetnih podataka te razdvajanje malih obiteljskih gospodarstava i većih farmi na kojima bi proizvodnja bioplina mogla biti ekonomski isplativa. Pošto farme u svojem svakodnevnom radu troše velike količine energije dio te energije bi mogle kompenzirati ili u potpunosti zamijeniti iz obnovljivih izvora energije te je zato dobro znati koliki su realni potencijali za bioplin u sektoru stočarstva u Hrvatskoj.

Symbols/Oznake

GV	- live stock unit, kgs - indeks težine	O_x	- organic matter factor, % - factor organske tvari
N	- number of animals per farm - broj životinja po farmi	V_{BG}	- annual volume of biogas, m^3 - godišnji volumen bioplina
m	- average weight of the animals, kg - prosječna masa životinje	X_{DM}	- conversion factor, m^3V_{BG} /kg D_m - konverzijski factor volumena bioplina i suhe tvari
t	- time spent in the barn, % - vrijeme provedeno u staji	P	- biogas potential, kW - potencijal bioplinskog postrojenja
V_a	- volume of manure, m^3 - godišnji volumen gnojiva	V_{BGd}	- daily volume of biogas, m^3 - dnevni volumen bioplina
V_{GV}	- annual amount of manure per GV (m^3/GV·a) - godišnji volumen gnojiva po GV	E_{BG}	- biogas energy potential, kWh / m^3 - energetski potencijal bioplina
D_m	- amount of dry matter, kg - masa suhe tvari	η	- efficiency of the gas engine, % - korisnost plinskog motora
D_x	- dry matter factor, % - factor suhe tvari	ω	- ratio of electrical/heat energy - omjer električne i toplinske energije

1. Introduction

In a time when we are faced with constant increase in fossil fuel prices, energy efficiency and possibilities of using some form of renewable energy sources becomes crucial in an every day agricultural process. In this research Croatian farming sector was observed and the possibilities for biogas production were considered. After considering basic agricultural information on animals and farms situation it was decided to put the focus on cows and pigs sector when considering biogas potential in Croatia. Other species, although present in Croatia are just not respectable factor to be considered (sheep, goats, poultry, etc.). Cows and pigs are widely spread in Croatia with a few farms that present a respectable biogas potential. One of the biggest problems of Croatian agricultural sector, in general, is some former measures and approaches to agricultural production. The present situation is characterized with a lot of small family farms which do not represent economically viable enterprises. This means a few pigs or cows and maybe a few chickens represent the average Croatian family farm. These kinds of farms do not have any kind of biogas potential and basically represent waste of energy regarding biogas production. Biogas potential of family farms with geographic background (county allocation) is interesting information for finding out how much energy is dissipated and lost because of the inefficient agricultural system [1]. Possibilities for improving this situation are presented in the following paragraphs. Other information that is presented in the paper is biogas potential for bigger farms (enterprises) that actually have significant possibilities for biogas production [2]. These technical possibilities are followed with economic viability. To achieve this, government needs to give stimulating procedures for farmers to make biogas production more economically viable. Feed In tariffs are not enough for stimulating farmers to go into biogas production but a better legal and financial framework is necessary. Farms are big consumers of energy, primarily electrical, and the possibilities of reducing that consumption are very important [3-4]. With the tougher competition on Croatia agricultural sector and Croatian approach to the EU, producing agricultural products (milk and meat) as cheap as possible would make all the difference. And since production (including energy) costs determine the final product price, reduction of energy costs becomes more and more important. Biogas production comes as a possibility for reduction of energy consumption by farms in general and possibility of extra profit from selling electricity and heat. [5]

2. Methodology

The way of calculating biogas potential is made by the number of animals since this is the best choice in Croatia. The reason for this is the lack of quality data in this sector especially for larger farms. Croatia had an agricultural census in 2003. which gave a lot of quality information for family farms. Different potentials are calculated regarding Croatian counties, sectors, large farms with the biggest potential. As already mentioned Croatia has a lot of small farms, less than 50 cows. These farms present biogas potential only if gathered in a group of farms that are in a process of collecting manure. This is not economically viable for now so their biogas potential is expressed only as a group but their real potential is almost impossible to use [6-7]. Only possibility is heavy governmental funding for group collecting of manure but this is not likely in the near future. For this section detailed studies of transport costs and operations is needed. This

paper tries to present what is the total potential of biogas production, from cows and pigs, in Croatia since this question has not been properly covered in the past. This means no actual and specific data are present. As said, the process of calculating biogas potential was done with number of animals as a primary source for data calculating. Simplified process of calculating biogas potential (energy outputs) in this paper was as follows: First GV index is calculated (Live stock unit). The thing we know is the connection between GV index and mass of the animal [8].

$$GV = N \cdot m \cdot t / 500. \quad (1)$$

Next step is calculating annual volume of manure (m^3) based on the number of animals.

$$V_a = \sum (GV \cdot V_{GV}). \quad (2)$$

Amount of manure is set depending on the animal (cow, pig, etc.)

The volume of biogas is calculated by multiplying the volume of manure with factors of dry and organic mater which also depends on the animal for which the calculation is made.

$$D_m = V_a \cdot D_x \cdot O_x, \quad (3)$$

$$V_{BG} = D_m \cdot X_{DM}. \quad (4)$$

After having calculated the amount of biogas electrical and heat power for the produced biogas was calculated.

$$P = V_{BGd} \cdot E_{BG} \cdot \eta / (1 + \omega). \quad (6)$$

With this data potential for Croatian Counties and larger farms was calculated. The main challenge was to get and gather all the relevant information, group them and summarize them in a table form.

The parameters used in the previous equations are presented in the Table 1.

Table 1. Parameters used in the calculations

Tablica 1. Parametri korišteni u proračunu

t	90	%
O_x (average)	80	%
E_{BG}	6,5	kWh / m³
ω	0,57	
X_{DM} (average): Cows / Krave Pigs / Svinje	 0,37 0,45	 m^3/kg m^3/kg
D_x (average): Cows / Krave Pigs / Svinje	 8 6	 % %
V_{GV} (average): Cows / Krave Pigs / Svinje	 17 11	 m^3 / (GV*a) m^3 / (GV*a)

As already mentioned these equations represent simplified overview of biogas potential calculation and its methodology. [9-10]

3. Results

The results show the biogas potentials for two main agricultural animals in Croatia. The potentials are presented for cows and pigs. All the other categories, although present in Croatia, does not represent respectable potential regarding biogas. Primarily sheep, goats and poultry. They are mostly breed on small family farms and don't represent enough potential.

3.1. Cows

In the Table 2 number of cows in Croatia throughout the last 11 years was presented. The trend of growth is visible especially in the last few years. The thing interesting in this table is the fact that numbers of cows on enterprises are growing which is the most important thing when it comes to biogas potentials [9].

Table 2. Total number of cows in Croatia under recording

Tablica 2. Krave obuhvaćene uzgojno – selekcijskim radom u Hrvatskoj

Year / Godina	Total number of cows / Ukupan broj krava	Number of cows under recording / Krave obuhvaćene uzgojno – selekcijskim radom	
		Family farms / Obiteljska gospodarstva	Enterprises / Farme
1997	233207	62205	3602
1998	230650	75921	6224
1999	228014	80198	6218
2000	214666	85459	7439
2001	219782	91235	7606
2002	224078	101157	7367
2003	223954	133064	6895
2004	229042	158508	7344
2005	231633	167504	8531
2006	241084	174615	10512
2007	234671	168493	11134

It is important to say that because of the past agricultural system Croatia still has a lot of small family farms that have just a few cows. Those farms definitely do not represent a strong potential regarding biogas production but they are still quite important so we could know what amount of power from biogas with the present number of cows is possible in Croatia. The other aspect of importance is not technical but the economical impact for those small family farms that have just a few cows. In the future text the total potential for those "small farms sector" will be shown. As already mentioned two major categories are presented in this paper: family farms and enterprises. Family farms as shown in the Table 2 represent the majority when it comes to number of cows and breeders. However their biogas potential is not usable, although in total very big, because of small

divided and dislocated family farms. The number of cows are calculated as a sum of four common breeds (Simmental, Holstein, Brown breed, Meat breeds).

As shown in Table 3 Croatian family farms are quite small with an average of around 5 to 10 cows per a breeder. This is obviously not an economically viable production of milk or meat. This situation is inherited from the previous governmental system which basically didn t encourage people to invest and spread their farms regarding number of cows. As a result we have a situation of divided and dislocated family farms whose energy potential regarding biogas is basically impossible to valorize. Unfortunately the total of 26 MW of potential electrical and 45,6 MW of heat power stays unused. Possible solutions for this problem are explained in the conclusion in a more detailed way. The best possible solutions and possibilities for biogas plants in Croatia are larger enterprises that have enough animal to support economically viable biogas production. By current status regarding financial and legal framework, farms with more than 100 cows can be considered for this possibility with a side usage of other agricultural materials for their digesters. Farms with more than 500 cows have the possibility of economical biogas production by them selves. This analysis was conducted in Croatia during CIP Intelligent Energy Europe Program GERONIMO [7] (Getting Energy Reduction ON Agendas in Industrial Manufacturing Operations) which had a task and one of the outcomes to build an online biogas calculator available to all the farmers and energy experts. The above figures are for calculation based on only depending on manure produced by the animals and not using additional biomass for the digester. Using additional biomass to feed the digester makes the whole process more profitable and more economically viable. Two major issues and one minor one are noticed that directly influence the profitability and break-even period in biogas production. One is equipment price and other is feed-in tariff for electricity produced from biogas. Also a plus in the economic calculation would be the possibility of access heat utilization which is not the case on most of the Croatian farms. It is also important to say that the technology, its price and availability are becoming more favorably for the farmers and other investors so it is expected that in the near future the break-even period becomes shorter based on cheaper and more available equipment. Other issue is the feed-in tariff which is based on 1,2 Croatian Kuna for kWh of produced electricity

Table 3. Biogas potential on family farms (cows) in Croatia, for power and heat

Tablica 3. Potencijal za proizvodnju električne i toplinske energije iz bioplina na obiteljskim gospodarstvima (govedarstvo) u Hrvatskoj

County / Županija	Number of breeders / Broj uzgajivača	Number of cows / Broj krava	Average (cow/ breeder) / Prosjek (broj krava / broj uzgajivača)	Biogas potential / Potencijal za proizvodnju električne energije iz bioplina, kW	Available heat / Raspoloživa toplina, kW
Zagrebačka i Grad Zagreb	3705	20820	5,62	3225	5658
Krapinsko - zagorska	1549	5608	3,62	869	1525
Sisačko - moslavačka	1660	13475	8,12	2087	3661
Karlovačka	1184	6819	5,76	1056	1853
Varaždinska	1023	5750	5,62	891	1563
Koprivničko - križevačka	3108	26223	8,44	4062	7126
Bjelovarsko - bilogorska	3056	27593	9,03	4274	7498
Primorsko - goranska	267	856	3,21	133	233
Ličko - senjska	716	3330	4,65	516	905
Virovitičko - podravska	688	5932	8,62	919	1612
Požeško - slavonska	619	4670	7,54	723	1268
Brodsko - posavska	934	7946	8,51	1231	2160
Zadarska	194	1035	5,34	160	281
Osječko - baranjska	1503	13102	8,72	2029	3560
Šibensko – kninska	223	1558	6,99	241	423
Vukovarsko - srijemska	1421	14310	10,07	2216	3888
Splitsko - dalmatinska	48	349	7,27	54	95
Istarska	365	2413	6,61	374	656
Dubrovačko – neretvanska	120	607	5,06	94	165
Međimurska	670	5470	8,16	847	1486
TOTAL / UKUPNO	23053	167866	7,28	26001	45616

from biogas plant. Possible increase of this feed-in tariff would mean an increase of economic viability of a biogas plant. In the Table 4 potentials for enterprises (bigger farms) are shown.

Data from the Table 4 are the real and usable potentials for larger farms that can be used now already in economically viable way. Table 4 shows 1,72 MW potential of electrical energy from larger farms and 3,01 MW of heat energy. One of the problems that comes up is the consumption for heat energy. If we consider the need for heat energy for the digesters (around 33%) we still have quite a large amount of unused heat energy (around 2 MW). This energy could be used for heating purposes especially greenhouses, driers but unfortunately this is not the case since majority of the stated farms do not have the required equipment.

3.2. Pigs

Another section when talking about biogas potential from farming sector would be pig farms. The situation is quite similar as in cow sector regarding distribution and potentials. Also there is a large number of private small farms with a few pigs that can t have any kind of economically viable production of biogas. But their number is quite important for the general overview and possibilities for biogas production. The other section is big pig farms with thousands of animal that also have the possibility for economically viable production of biogas [10].

Table 5 shows quite a similar picture as the calculated biogas potential from cows on family farms in Croatia. Quite a big potential of 22,77 MW of electrical power and

Table 4. Biogas potential on larger farming enterprises (cow) in Croatia, for power and heat

Tablica 4. Potencijal za proizvodnju električne i toplinske energije iz bioplina na farmama (govedarstvo) u Hrvatskoj

County / Županija	Enterprises / Farma	Number of cows / Broj krava	Biogas Potential / Potencijal za proizvodnju električne energije iz bioplina, kW	Available Heat / Raspoloživa toplina, kW
Karlovačka county	Pro Milk	476	74	130
Zadarska county	VIGENS	677	105	184
	Vrana Biograd	453	70	123
Osječko-baranjska county	Agrobovis	308	48	84
	B.I.J.A.F.	387	60	105
	Belje Čeminac	479	74	130
	Belje Mitrovac	430	67	118
	Belje Popovac	712	110	193
	Belje Topolik	348	54	95
	Belje Zeleno Polje	256	40	70
	Grube	330	51	89
	Hana Breznica	386	60	105
	Hana Niza	306	47	82
	Ipk Mf "Holstein"	883	137	240
	Krndija	779	121	212
	Lactis	165	26	46
	Opg Tokić	306	47	82
	Osilovac	343	53	93
	Pz Osatina-Tomašanci	368	57	100
	Salaš	340	53	93
	Satnica Milk	137	21	37
Vukovarsko-srijemska county	Domaćinović	363	56	98
	Pz Osatina-Ivankovo	902	140	246
	Vupik Jakobovac	855	132	232
	Vupik Vera	110	17	30
		11099	1720	3017

almost 40 MW of heat energy. Unfortunately the same explanation applies here as for cows biogas potential from family farms. Farms are small and dislocated and manure that comes from the animal can t be used for economically viable biogas production. Better situation is regarding large pig farms (enterprises) with a large number of animals that could have economically viable biogas production. Table 6 shows those farms and their biogas potential, both electrical and heat.

Table 5. Biogas potential on small family farms (pigs) in Croatia, for power and heat

Tablica 5. Potencijal za proizvodnju električne i toplinske energije iz bioplina na obiteljskim gospodarstvima (svinjogojstvo) u Hrvatskoj

County / Županija	Number of pigs / Broj svinja	Biogas Potential / Potencijal za proizvodnju električne energije iz bioplina, kW	Available heat / Raspoloživa toplina, kW
Zagrebačka županija	160490	2116	3712
Krapinsko-zagorska županija	60356	796	1396
Sisačko-moslavačka županija	131675	1736	3046
Karlovačka županija	40453	533	935
Varaždinska županija	107752	1421	2493
Koprivničko-križevačka županija	163186	2152	3775
Bjelovarsko-bilogorska županija	167774	2212	3881
Primorsko-goranska županija	1370	18	32
Ličko-senjska županija	4745	63	111
Virovitičko-podravska županija	89017	1174	2060
Požeško-slavonska županija	73902	975	1711
Brodsko-posavska županija	127382	1680	2947
Zadarska županija	4491	59	104
Osječko-baranjska županija	257421	3394	5954
Šibensko-kninska županija	6275	83	146
Vukovarsko-srijemska županija	187497	2472	4337
Splitsko-dalmatinska županija	24058	317	556
Istarska županija	11915	157	275
Dubrovačko-neretvanska županija	1818	24	42
Međimurska županija	82663	1090	1912
Grad Zagreb	22655	299	525
TOTAL / UKUPNO	1726895	22771	39950

From the Table 6 we can see biogas potential regarding electrical power and heat for bigger farms in Croatia. These farms could be considered as biogas producers regarding their animal number. In this section the total potential is 3,88 MW of electrical output and 6,8MW of heat energy. The same thing applies for excess of heat energy after the digester is satisfied (around 4,5 MW). One of the possible solutions for significant amount of biogas potential on family farms, both cow and pig farms, could be strong legal governmental initiative that would encourage farmers to extend their farms and try to increase the number of animal on their farms. This needs to be followed up with governmental financial initiatives that could help the farmers directly. One of the initiatives should also be the initiative to stimulate farmers to ground their land by surface. This would also lead to bigger family farms with higher potentials for agricultural production. Regarding the dispersion and the small number of animals per family farm one of the initiatives could be the possibility of establishing municipal biogas plants where manure can be transported and concentrated. This could work out for villages and small towns with higher agricultural production. One of the most important issues that need to be investigated is the transportation costs and the legal framework for aggregating more farms [9-19]. Also one of the major issues is connecting farmers by spreading the entrepreneurship spirit which could lead to possible cooperatives [21]. Danish experiences are showing cooperative biogas production can be economically viable and positive for the local community. Beside governmental and municipal initiative, initiative coming from the farmers is crucial for starting cooperative biogas, heat and electricity production. Experience shows that direct financing, at least partial, by the farmers is necessary but also most challenging. Farmers need to be involved in the finance structure and in the managing operations of the biogas plant. That way they could actively participate in the decision making processes which has proven to be a successful model in the Denmark case. One more positive impact from energy cooperatives is the chances

Table 6. Biogas potential on larger farming enterprises (pigs) in Croatia, for power and heat
Tablica 6. Potencijal za proizvodnju električne i toplinske energije iz bioplina na farmama (svinjogojstvo) u Hrvatskoj

Larger Farms / Farme	Total number of pigs / Ukupan broj svinja	Biogas potential / Potencijal za proizvodnju električne energije iz bioplina, kW	Available heat / Raspoloživa toplina, kW
Belje Darda	14050	397	696
Belje Malo Kneževo	7953	225	395
Belje Brod Pustara	8546	241	423
Belje Andrijaševci	4693	133	233
Belje Rokovci	2668	75	132
Reprocentar d.o.o.	1388	39	68
Farma ŽITO d.o.o. Forkuševci	23131	654	1147
Farma ŽITO d.o.o. Magadenovac	17860	505	886
Farma ŽITO d.o.o V.Branjevina	6290	178	312
Farma Lipine d.o.o.	5494	155	272
Farma Senkovac d.d..	13557	383	672
KZ-Požega	1589	45	79
Farma Dubravica d.d.	5746	162	284
Farma Stočar	2063	58	102
Agromeđimurje	5970	169	296
Krmiva d.o.o.	3272	92	161
Farma Gavrilović	2682	76	133
Farma PP Orahovica	2843	80	140
Svinjogojska farma Rovišće	5240	148	260
Farma Sizim d.o.o.	2249	64	112
TOTAL / UKUPNO	137284	3879	6803

for farmers to improve their manure management opportunities. With Croatia as an EU candidate country stricter rules regarding manure management is expected so cooperative manure management would help farmers in their manure management issues.

3.3. Carbon footprint

Methane emission produced by Croatian family farms and farm enterprises is an interesting factor to analyze since methane is 21 times more potent than CO_2 regarding green house effect. If all Croatian biogas potential of family farms would be utilized (both cows and pigs) 59 246 tons of CH_4 would be saved which matches 1 244 166 tons of CO_2 equivalent. Also if all farm enterprises (both cows and pigs) would utilize their biogas potential 4 357 tons of CH_4 can be saved which matches 91 497 tons of CO_2 equivalent. A significant fact is the electrical energy produced from biogas and its impact on the carbon footprint. All the electrical energy produced from biogas can replace and decrease the production of electrical energy for the national grid. If all biogas potential of family farms would be utilized (both cows and pigs) 343 GWh of electrical energy could be produced what matches the emission of 112 504 tons CO_2 [22]. If all farm enterprises (both cows and pigs) would utilize their biogas potential 24 GWh of electrical energy could be produced what matches the emission of 7 872 tons CO_2 [22]. Once again we have to say utilizing biogas potential and reducing carbon footprint through family farms is not realistic but utilizing biogas on farm enterprises is a realistic option which we can expect in the future.

4. Conclusion

Croatian biogas potential regarding cows and pigs could be considered quite big if we look at the total number of animals, especially on family farms. However already mentioned barriers are making it very hard to use all of those potentials. There are a few possibilities for trying to overcome those barriers, which are explained in the previous paragraph but there will be still quite a long time for a significant progress in this area. The things that have a bright future are big farms and enterprises which needs to be stimulated more strongly. That means existing farms that have biogas potential but also future farms that are going to be build in the future period. Both legal and financial, those farms needs to be stimulated to be a biogas producers, not only because of the energy they can produce or converse but because the fact that biogas production effectively deals with manure issues and manure management on farms in general. [20, 23-26]

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