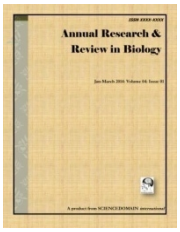

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Biogas from Animal Manure – Perspectives and Barriers in Bulgaria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AZ managed the literature searches, collected information about technology, and development of biogas production in Bulgarian conditions and wrote the first draft of the manuscript. Author DP has discussed the data about the total amounts of manure and manurs distribution under the animal species. Author AA managed the analyses of the study and wrote the last draft of the manuscript. All authors read and approved the final manuscript.

Review Article

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ABSTRACT

This paper aims to review the perspectives and barriers before production of biogas from animal manure in Bulgaria.
The share of methane emissions from the agricultural sector in Bulgaria occupies 18 % and stored animal manure is its biggest source. The use of animal manure for production of biogas could reduce these emissions. Biogas market in Bulgaria is not well developed yet, but the potential of biomass for biogas production is promising. Residues and waste from animal production as well as crop residues are important renewable energy sources for Bulgaria as raw materials for biogas production. Animal manure availability from cattle- and pig- and poultry farms in Bulgaria are presented. The content of N, P and K in the manure is discussed in view of further use of the residues of biogas production as soil nutrients. Advantages and barriers to biogas production in Bulgaria are discussed.
Presented data reveal a promising resource for biogas production by anaerobic digestion. The total energy of methane from pig manure is estimated to the value 6703 PJ.

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Additionally about 25188 PJ from cattle manure are available, and from poultry roughly other 3684 PJ.
The comparison of needs of N, P and K for soil fertilization with the quantities of these elements, available from animal manure allows concluding that the biomass residues from biogas production could play considerable role in soil fertilization.
To fasten and enlarge the introduction of anaerobic digestion of manure it is necessary to formulate as mandatory requirement in applying for subsidy: every farmer should build concrete platforms for storage of fresh manure (from pigs) and lagoons (though open). It assures also the ecological advantage to prevent nitrogen contamination of soil, and groundwater.

Keywords: Animal manure; biogas; biogas perspectives; nutrient management; Bulgaria.

1. INTRODUCTION

The use of animal manure for production of biogas has positive environmental impact due to reducing carbon dioxide (CO_2) and methane (CH_4) emissions - the cause for global warming [1]. According to Executive Environment Agency [2], the share of emissions of methane, emitted by the agricultural sector in Bulgaria, occupies 18%. Present situation with increasing energy demand in world scale also stimulates processing animal manure for biogas production. Bulgaria's national energy target for 2020 presumes the share of energy from renewable sources in the gross final consumption of energies to achieve 16% [3]. Thus the production and higher use of biogas will be necessary to reach this national target. Biogas production from animal manure in Bulgaria is still undeveloped due to high starting investments; despite there is a high potential for its future implementation. The recently introduced Renewable and Alternative Energy Sources and Biofuels Act [4] with very good feed-in tariffs (ranging between 433 and 119 BGN per kWh) has led to an increased interest to construction of biogas plants in the last time.

2. BIOGAS PRODUCTION IN BULGARIA

2.1 General

Methane fermentation is an old means of energetic conversion of the biomass. The history of anaerobic digestion from the time this phenomenon was first reported in 17th century was described by Abbasi et al. [5]. The use of biogas in developing countries as well as its development in the world and particularly in Europe is discussed too. The details of production process and characterization of biogas were reviewed by Balat and Balat [6]. Biogas is generated from organic digestion under anaerobic conditions by mixed population of microorganisms. It is an alternative energy source commenced to be utilized both in rural and industrial areas at least since 1958.

Advantages of biomass from animal manure are well known. Generally, anaerobic digestion of animal manure solves three problems: unpleasant odour management, creation of new source of bioenergy and the reduction of green house gases (GHG) emissions [7]. In addition, anaerobic digestion reduces water pollution and kills pathogen and weed seeds [8]. The digestate (resultant slurry) after some additional processing may be used to replace commercial fertilizer [9,10]. The details and perspectives of biogas technology in European countries have been reviewed [11].

2.2 Background

In Bulgaria first pilot biogas installations have been created between 1980 and 1988 [12], but after 1989 these have been snapped up. First working biogas installations in the past have been situated close to Silistra and Pleven in big poultry farms.Later, a scientific project on biogas from animal manure has been developed in Bulgarian Agricultural Academy in frame of which a biogas installation for small size agricultural farms has been designed [13]. The study has shown that an optimal number of 45 head of cattle, 10 pigs and 230 hens can ensure a sustainable production of biogas for heating farmer's house. Recently, a paper describing new pilot-scale biogas plant with a computerised monitoring and control system developed in the Institute of Microbiology in Bulgarian Academy of Sciences has been published [14]. This biogas plant will be very useful for developing optimised technologies for anaerobic digestion and co-digestion of different organic wastes and for multidisciplinary studies of this kind of processes. Last publication some months ago has been Master Thesis [15] from Aalborn University. It assesses the socioeconomic impact from the implementation of biogas production in Bulgaria.

2.3 Estimation of Perspectives

The perspectives for biogas production from animal manure in Bulgaria have been estimated on the basis of existing data about animal breeding holdings. Data about bovine, pig and poultry holdings have been taken from Statistical Yearbook per 2012 [16]. The available resources for biogas production have been calculated on the basis of these data. The energy E in MJ, that can be obtained from animal manure M tons, can be calculated using the formula:

$$E= 22.6\ M/P_{CH4},$$

where P_{CH4} is methane yield from 1 ton and the energy from 1 m^3 methane is 22.6 MJ.

The composition of animal manure of different domestic animals in view of further use of digestate as soil nutrient has been presented. The possible quantities of producing digestate fertilizers have been estimated as well.

3. RESULTS AND DISCUSSION

The distribution of animal breeding holdings in Bulgaria by categories and economic size is presented in Fig. 1 in percents. First column summarizes bovine, sheep (24% of total agricultural holdings in Bulgaria), and the second one - pigs, poultry, and rabbits (about 8%). About 13.5% of total agricultural holdings in Bulgaria are mixed type livestock holdings (third column) and about 20% - mixed crops – livestock holdings (fourth column). Big agricultural holdings have economic size bigger than 250 000€, small ones - less than 25 000.

The distribution of animal breeding holdings in Bulgaria is in favour of big number of small farms (3-10 heads) and small number of big farms. Small holding take more than 60% in all categories, while the part of big ones is less than 1%.

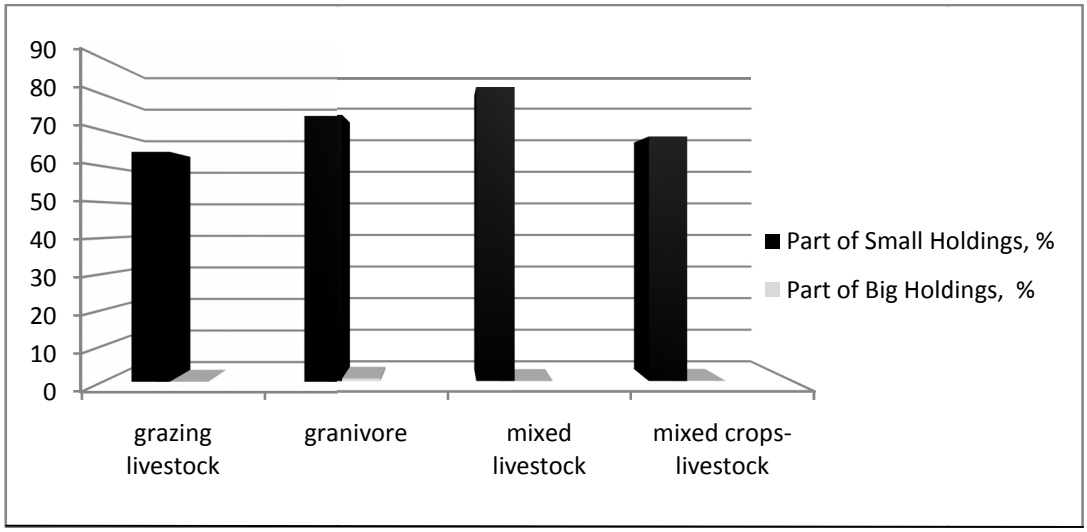

Fig. 1. Distribution of agricultural holdings in animal husbandry in Bulgaria

From the point of view of anaerobic digestion technology the bovine and pig big farms are of the major interest. According to official statistical data of Faostat [17] the distribution of livestock in Bulgaria is as follows: poultry birds – 84.39%; Sheep and Goats – 9.15%; Cattles and Buffaloes – 2.94% and Pigs – 3.25% (Fig. 2).

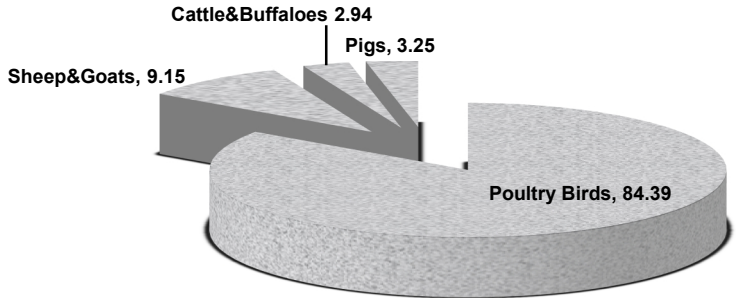

Fig. 2. Distribution of livestock in Bulgaria.

Pig farms have big potential for biogas production. Their distribution in Bulgarian regions is presented on Fig. 3. Of course, big farms are more perspective for building of biogas installation. That is why only breeding farms with more than 500 sows and more than 50000 piglets are presented on the map. Nearly 50% of all pigs in Bulgaria are grown in 0.04% of the farms (average number – 5600 heads per holding, 76 holdings) farms with less than 9 sows represent 96% of all farms and have about 30% of all animals.

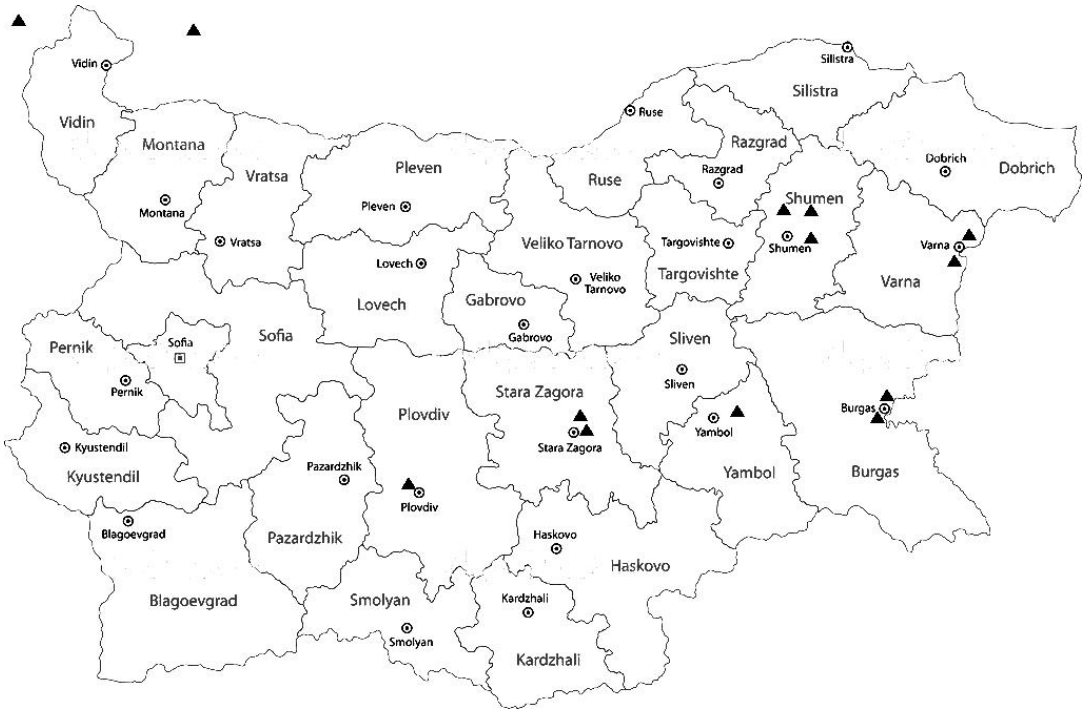

Fig. 3. Pig breading farms with more than 500 sows and more than 50000 piglets.

Bovine animals are even less concentrated. About 18 % of the animals are in herds with more than 50 heads (957 holdings with average 112 heads per holding). Family type farms with one or two cows represent 69 % of all farms and breed about 30 % of all animals.

On Fig. 4 the map of Bulgaria with bovine farms breeding more than 200 heads is presented. Most of these farms are situated in Northern Bulgaria. Only 8 farms of these have been breeding more than 500 heads.

On the next Fig. 5 the distribution of poultry farms in Bulgaria is mapped. Only the farms with more than 50000 hens and with capacity for breeding more than 1000000 chickens per year are presented. It should be mentioned that the first pilot biogas installations in Bulgaria have been created in the neighborhood of big poultry farms [12].

An important premise of anaerobic digestion is manure collection. Biogas installation needs a regular supply with enough row materials. That is possible if the manure is collected and stored in concrete platforms for storage of fresh manure (especially from pigs) and lagoons. Most of small scale farmers collect the manure in open air in the yard and use it as fertilizer in their own small size land. This gives them an economical advantage – low cost fertilizers; but there are ecological disadvantages – unpleasant smell, pollution of soil and underground water, higher emissions of CO_2 and CH_4. This also represents a barrier to the production of biogas from manure because of irregular and unsecure supply of raw material. Bigger farms collect the manure in semi solid faeces (ruminants) or in open lagoons (swine). Collected manure mostly is stored by drying on concrete platforms or in lagoons. At the moment it is not used but gives an opportunity for it's processing in the future for biogas production through anaerobic digestion and composting the residual biomass for fertilizers. The small

number of big livestock farms is the main barrier for organizing plants of anaerobic digestion. On the other hand, from technological point of view small farms are not prospective for biogas production, because could not supply regularly raw materials for the process of anaerobic digestion. There is a possibility for them to create cooperatives, but it is a long lasting process with specific organization and management. Other obstacles for anaerobic digestion are the long distance between the farms, the lack of governmental support, etc.

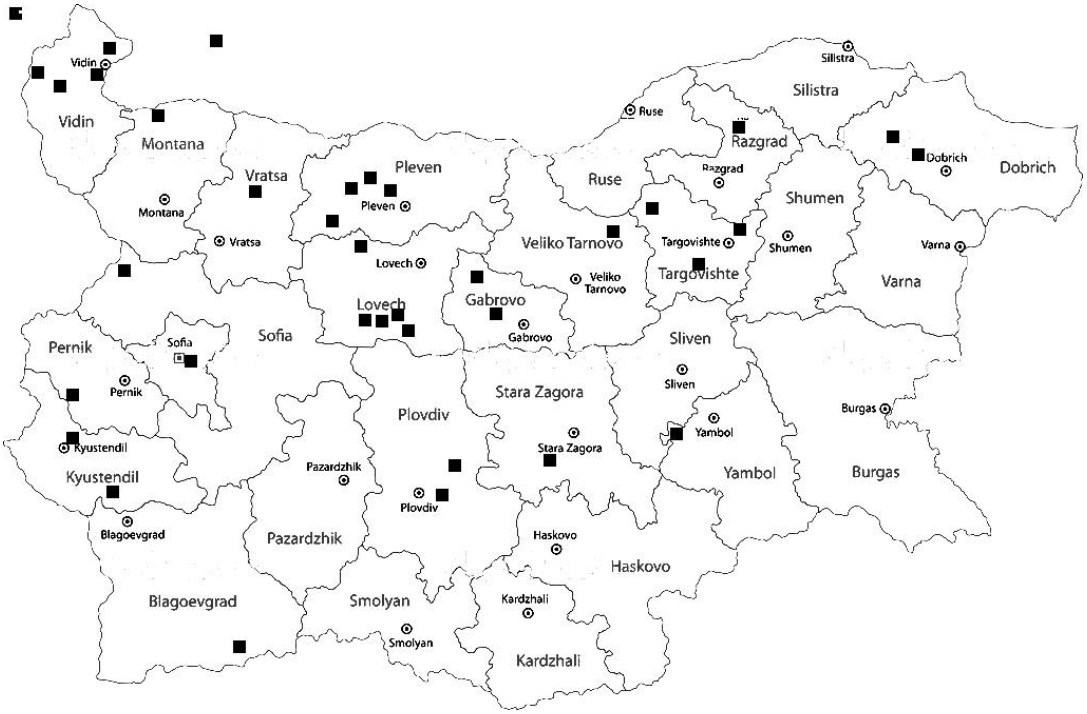

Fig. 4 - Bovine farms breeding more than 200 heads

The annual biogas potential in Bulgaria is estimated in [15] based on data from Ministry of Agriculture and Food [18]. Despite the small discrepancy with the data published in [18], the estimation [15] for biogas production in Bulgaria gives an acceptable energy value of 22.2 PJ. The biggest sources of animal manure in Bulgaria are the poultry farms. The manure of terrestrial poultry (approximately 85% [16]) is stored by drying on concrete platform. About 5% of manure (in small private holdings) is stored by drying on non-concrete platform. The rest of manure (mostly from fattening ducks for liver) is driven into open concrete lagoons, where is stored to drying. The total pig manure collected for 2010 is 1 412 372 tons and potential methane yield from 1 ton manure is estimated to 210 m^3 [19], so the total amount of methane released is 296 598 248 m^3/year. The total methane released from pig manure has an energy value about 6.7 PJ. The total cattle manure for 2010 being 6 634 240 tons and potential methane yield from 1 ton manure estimated to 168 m^3 [19], the total amount of methane released is 1 114 552 320 m^3/year. This means an estimated energy of about 25 PJ from cattle manure. Potential methane yield from 1 ton poultry manure is estimated to 210 m^3 [20]. The total amount of methane released per 2011 is estimated to be 138586137 m^3. This means that the potential of biogas production from poultry farms is significant and can be roughly assessed to 3 PJ. Total potential methane yield from cattle, pig and poultry manure is roughly assessed to approximately 34.7 PJ. It is bigger than the communicated [15] 22.2 PJ, because the data about the number of some animals (cattle, pigs and poultry)

in [18] are different from the used in [15]. Besides, in our estimation the total number of terrestrial poultry has been used.

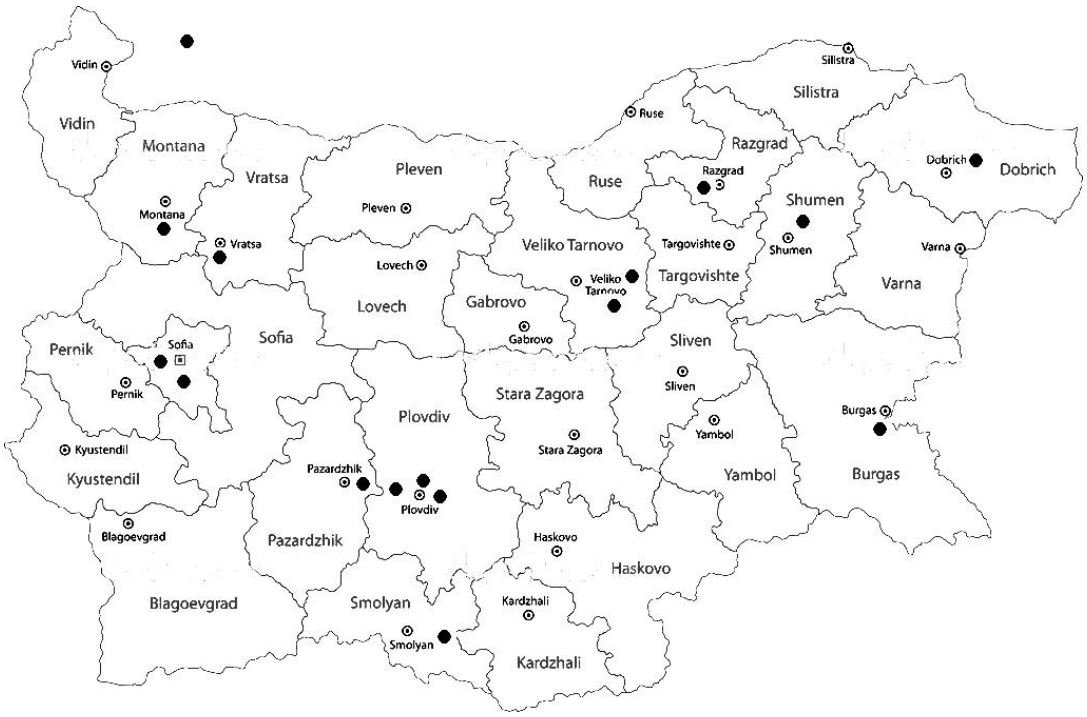

Fig. 5. Poultry farms with more than 50000 hens and 1000000 chickens per year

The content of nutrient elements N, P and K in the manure predefines the role that biomass residues from anaerobic digestion would play in soil fertilization. Data about the potassium content in the manure of domestic animals are presented in Table 1, according to Stojkov [19]. Total amount of potassium from domestic animals for 2010 is approximately 124 141 t.

Table 1 - Potassium from different domestic animals

Years	Total number sheep	Potassium from sheep, Ton/year	Total number pigs	Potassium from pigs, Ton/year	Total number cattle	Potassium from cattle, Ton/year
2000	2548884	164028,95	1 546 000	12 018,35	643000	30324,2
2005	1692500	113818,44	943 000	7 280,05	622000	29331,4
2010	1368000	92068,94	783 000	5 534,31	563000	26536,96

The chemical composition of fresh poultry manure in g/kg is presented in Table 2, according to [20].

Table 2. Chemical composition of fresh manure by species and categories poultry

Elements	Laying hens – g/kg	Broiler chickens – g/kg	Ducks– g/kg
Nitrogen – total	10-18 (average 14,2)	14-22 (18,3)	(22,3)
Phosphorus (as P_2O_5)	8-12 (10,3)	9-12 (10,7)	-
Potassium (as K_2O)	5-7 (6)	5-8 (7,8)	-

The total amount of nitrogen from poultry manure is calculated based on personal communication from D.Belorechkov - the president of the Union of poultry farmers [21]. Data are presented in Table 3.

Table 3. Total amounts of excrements for 2011 and nitrogen (ammonia) from poultry

Category birds	Total manure amount – ton/year	Total nitrogen amount – ton/year	Total ammonia amount – ton/year
Laying hen	312758	4441	5416
Chicken	350890	6421	7831
Ducks	112744	2514	3066

Total nitrogen and ammonia amount from all poultry species in Bulgaria is estimated to 13 376 t/year and 16 313t/year, respectively. Total amounts of phosphorus (as P_2O_5) and potassium (as K_2O) from poultry for 2011 in Bulgaria are estimated by the same way as for nitrogen in Table 3 and presented in Table 4. Total amount of phosphorus (as P_2O_5) and potassium (as K_2O) for 2011 are estimated to 6976 and 4593t/year, respectively.

Table 4. Total amounts of phosphorus (as P_2O_5) and potassium (as K_2O) from poultry in Bulgaria for 2011

Category birds	Total manure amount – ton/year	Total phosphorus amount (as P2O5) – ton/year	Total potassium amount (as K2O) – ton/year
Laying hen	312758	3221,4	1876,5
Chicken	350890	3754,5	2717

The needs of N, P and K in Bulgaria roughly is communicated to be 100kg/ha, 50kg/ha and 80 kg/ha [16]. Having in mind that total agricultural area in Bulgaria is 63765 sq.km=637 ha, the total needed amounts of N, P and K can be estimated to 64 t, 32 t and 51t, respectively. The comparison with the quantities of these elements, available from the calculations based on Table 3 and 4 allow concluding that the biomass residues from biogas production could play considerable role in soil fertilization.

Present situation in biogas production in Bulgaria is illustrated with Table 5 [22]. As it can be seen, there is no functioning biogas installation in Bulgaria at present, but the preparation for future plants construction is in action.

Table 5. Present situation for biogas production and utilization in Bulgaria

Name	Location	Feedstock	Utilization of biogas	Status
Tsarevets farm	Mezdra district	Cattle manure & maize	Electricity	In construction
Dobrich farm	Dobrich district	Animal manure & agricultural waste	Electricity & domestic water	Early planning stage
Montana landfill	Montana	Municipal waste	Purification & burning of biogas	In construction
Sozopol landfill	Sozopol	Municipal waste	Purification & burning of biogas	In construction
Rousse landfill	Rousse	Municipal & industrial waste	-	In construction
Suhodol landfill	Sofia	Municipal waste	CHP	In preparation
Kubratovo WWTP*	Sofia	Sewage sludge	CHP	In preparation

** WWTP = Waste Water Treatment Plant*

4. CONCLUSION

1. All presented data reveal a promising resource for biogas production by anaerobic digestion. The total energy of methane from pig manure is estimated to the value 6.7 PJ. Additionally about 25 PJ from cattle manure are available, and from poultry roughly other 3.7 PJ. The potential total amount of energy is about 34.7 PJ.

2. The comparison of needs of N, P and K for soil fertilization (estimated to 64 t, 32 t and 51 t, respectively) with the quantities of these elements, available from animal manure (phosphorus as P_2O_5 and potassium as K_2O for 2011 estimated to 6976 and 4593t/year, respectively) allows concluding that the biomass residues from biogas production could play considerable role in soil fertilization.

3. To fasten and enlarge the introduction of anaerobic digestion of manure it is necessary to formulate as mandatory requirement in applying for subsidy: every farmer should build concrete platforms for storage of fresh manure (from pigs) and lagoons (though open). It assures also the ecological advantage to prevent nitrogen contamination of soil, and groundwater.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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