Biogas Production Potential from Waste in Timis County

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Abstract
This work is a study of biogas production potential using as substrate the residues generated in the agricultural activities and the organic fraction from municipal wastes collected in Timis County. Data available in regional and national statistics have been reported to Timis County and used to calculate the potential quantity of biogas to be produced by anaerobic fermentation using as fermentable substrate residues generated in various human activities. To estimate the electric and thermal energy potential of the biogas, we considered the productivity of an average biogas plant couplet with a CHP unit with an efficiency of 40% net electric and 40% net thermal output and functioning 7500 hours per year. Processing data for the biogas production potential from livestock manure in Romania, we found that over 500 GWh of energy from biogas can be provided in one year. It is estimated that only half of the theoretical energy potential is technically usable by biogas investments. As for the crops residues, has been shown that the theoretical biogas potential is over 2900 GWh/year. Wastewater sludge can be converted in around 1700MWh/year, and the organic wastes available from municipal wastes can provide over 137 GWh/year. Another potential for renewable energy production in Timis County is the arable land uncultivated yearly, which can be used to cultivate energy crops, as raw material for biogas providing over 2800 GWh/year. All this quantity of biogas can be converted in numerous CHP biogas plants totaling an installed power of over 340 MWel.
This potential can contribute to reach the target for 2020 in Romania to build biogas plants totaling at least 195 MWel. installed power, with an output of 950 GW electric power.

Keywords: biogas, potential, renewable energy, residues, Timis

1. Introduction

Anaerobic digestion of organic residues and agricultural wastes is of increasing interest in order to reduce the greenhouse gas emissions and to facilitate a sustainable development of energy supply. Production of biogas provides a versatile carrier of renewable energy, as methane can be used for replacement of fossil fuels in both heat and power generation and as a vehicle fuel. Debates regarding the future of biofuels are strong; the main issues being discussed are food-versus-fuel, the energy balance, costs/prices, technologies applied, carbon foot print etc. Solutions to keep progress in biofuels technologies are already found: second generation of biofuels which uses non-food and feed materials. Virtually all types of biomass can be used as substrates in anaerobic fermentation for biogas production. The composition of biogas and the methane yield depends on the feedstock type, the digestion system, and the retention time [1]. The theoretical gas yield varies with the content of organic constituents in the biomass and their availability (for example, in the strong lignified wood, the carbohydrates as cellulose, hemicelluloses, are not available for hydrolysis, consequently, wood is not suitable for biogas production due to the slowly anaerobic decomposition). Historically, anaerobic digestion has mainly been associated with the treatment of animal manure and sewage sludge from aerobic wastewater treatment. Nowadays, most of the agricultural biogas plants digest animal manure

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with the addition cosubstrates to increase the content of organic material for achieving a higher gas yield. Typical cosubstrates are plant biomass, mainly harvest residues, organic wastes from agri-food industries, collected municipal biowaste from households and energy crops.

Biogas technology brings multiple benefits in environment protection, additional income in rural areas, creating new jobs, besides production of renewable clean energy. Biogas sector is strong connected with agriculture and residues from agri-food sector, as virtually any organic residue can be anaerobicaly fermented and converted from pollutant into fertilizer and into green energy. Consequently, most biogas plants are constructed around the world in the proximity of agricultural exploitation, most of them using animal manure as inoculums containing anaerobic microorganisms necessary to develop methane fermentation. While in other countries from the E.U., thousands of on-farm biogas plants are operated (for example, in Germany, around 5000 biogas plants are in operation – the country with the highest number of biogas plants in Europe), in Romania none large-size biogas plant operates on-farm. The only pilot-scale on-farm biogas plant in Romania is in operation at the research farm belonging to University of Agricultural Science from Timisoara (projected by Vintila et al. and constructed with founds from the Romanian Government and World Bank) [3]. However, new drivers will lead to the development of biogas sector in Romania. The most important driver is the new legislation that promotes the production of energy from renewable resources, which is applicable in the final version starting by the end of 2011. This legal frame [4, 5] will lead to the development of the renewable energy sector, including biogas sector in Romania. Timis County is situated in the western part of Romania and is the county that covers the largest agricultural surface among Romanian counties. For this reason, and because our University is located in this county, we decided to study the potential of this region to provide raw materials to be used as substrate in the anaerobic fermentation for biogas production. The calculations made in this work provide important data that can be found useful for companies and developers interested to exploit this potential for renewable energy production.

2. Materials and methods

This study was made using statistical data regarding availability of organic wastes, that we considered to be suitable as substrates for anaerobic fermentation, published in the Statistical Yearbook of Romania [6] and the Regional Waste Management Plan - 5 West Region [7]. For calculation of methanogenic potential of each substrate we used the data published in previous works [9-12] and to compare the electric energy potential, with the consume of the electricity, we used public information made available by the local provider of electricity [13]. A synthetic presentation of data used to calculate the biogas production potential is described below.

1. Agriculture in Timis County

From the total surface of the county, which covers 869670 ha, the agricultural surface represents 80%, totaling 698638 ha (from which 533500 ha is arable land) [6]. Timis County is the largest county in Romania, including the largest agricultural surface. The planes covers 75.9% from the total surface of the county, this surface being suitable for intensive agriculture. Another important aspect is the uncultivated agricultural surface, which in 2010 was around 80000 ha, representing around 15% from the total arable land (personal communication, APIA). Regarding the animal husbandry sector, the livestock including the most important animal categories is presented in Table 1.

Table 1. Livestock including the most important animal categories in Timis County [6]

Cattle	Swine	Sheep and Goats	Horses	Poultry
47 722	588 471	543 111	8 175	2 012 060

The animal husbandry sector is very important for biogas production, as the animal wastes represents an important source of fermentable substrates and the main source of methanogenic microorganisms to be used as inoculums to initiate anaerobic fermentation and biogas production from other substrates.Regarding the residual plant biomass produced in agricultural activities in the county, was estimated based on the main crops production as in Table 2.

Table 2. Main crops and crops residues in Timis County [6]

	Cereals (wheat, barley, oat, rye)	Corn grain	Oil plants	Vege-tables
Total production (t)	478188	438132	74065	113164
Plant residues after harvesting (% from crops)	25%	200%	120%	35%
Plant residues after harvesting (t)	119547	876264	88878	39607

The plant residues represent in most of the farms undesirable waste, which is in many cases burned on the field. This way, the energy contained in the residual biomass is wasted, it is an unsecure practice, it pollutes, and the ecosystem is affected. This residual biomass can be collected, processed and fermented to produce biofuels (ethanol or biogas).

2. *Wastes produced by the population of Timis County*

The most important quantity of fermentable solid wastes produced by the population of Timis County represents the municipal organic wastes. Each inhabitant of the county produces yearly 420 kg total waste, from which approximately 50% is biodegradable, hence fermentable. This means that the total population of Timis County, which counts around 687 000 inhabitants, generates around 144 000 tones biodegradable waste/year.

Table 3 contain the principal amounts of organic solid wastes collected in one year in rural and urban communities from Timis County.

Table 3. Collected organic waste [7]

Collected urban and rural organic waste in one year	Collected quantities (t)
Kitchen, garden and yard waste	111090
Organic waste from institutions, economic entities, commerce	68530
Residues from public gardens and parks	6272
Wastes from markets	5612
TOTAL	191504

Regarding wastewater, industrial effluents and sewage, wastewater treatment plants collect in Timis County around 3400 tons of solid sludge yearly [7]. Considering that the average dry matter content of the sludge is 8.7%, results a production of 296.6 tons of dry sludge containing 90% organic matter.

3. *Calculation model of biogas and energy yields*

The biogas yield of the individual substrates varies considerably dependent on the content of organic substance, and composition (Table 4).

Using data in tables 1 – 4, we made the estimation of the quantities of biogas that can be produced from various substrates. To calculate the potential of energy production, we started from the consideration that the produced biogas will have the minimum methane content, of 60%. This means that 1 m^3 of biogas contain minimum 6 kWh of energy. If the biogas is burned into a cogeneration of heat and electric power unit (***CHP unit***), with an average efficiency of 40% net electric output and 40% net thermal output, and having an average of 7.500 hours of functioning in a year, this technology will provide approximately ***2.4 kWh electric energy*** and same amount of thermal energy from 1 m^3 of biogas. This is a pessimistic scenario, as the biogas can have more than 60% methane content and new technologies in CHP units develops efficiencies over 80% (overall energy efficiency) and the functioning time of a CHP unit is usual more than 8000 hours.

Table 4. Biogas yields from various substrates [2]

Substrate	Obtainable biogas Litre/Kg D.M.	Average methane content, %
Wheat straw, whole	367	78.5
Wheat straw, chopped at 3 cm	363	80.2
Wheat straw, micronized at 0.2 cm	423	81.3
Alfalfa	445	77.7
Grass	557	84.0
Sugar beet leaves	501	84.8
Tomato stems	606	74.7
Corn stover	214	83.1
Tree leaves	260	58
Barley straw	380	77
Rice straw	360	75
Flax and hemp stems	369	58
Cow manure	260 – 280	50 – 60
Pig manure	480	60
Horse manure	200 – 300	66
Sheep manure	320	65
Poultry manure	520	68
Human feaces	240	50
Sewage sludge	370	50 – 60

3. Results and discussion

Animal waste (composed mainly of manure, and other organic matter, as bedding, feed residues etc) is the most used substrate in biogas production around the world. Animal manure contains essential microbiota for anaerobic fermentation for production of biogas reach in methane. Using statistical data presented above, we can calculate the quantity of biogas that can be produced using the whole quantity of waste produced by animals in Timis County (Table 5).

Table 5. Biogas production potential from animal waste

Animal categories	Cattle	Swine	Sheep and Goats	Horses	Poultry
Nm^3 Biogas/1000 kg live animal/day	3.05	2.62	4.15	3.31	6.21
No. of animals/Timis County	47722	588471	543111	8175	2012060
Average weight of an adult animal (kg)	344	110	24	412	2
Total weight (t)	16416	64731	13035	3368	4024
Nm^3 biogas/day	50.069	90.995	54.095	11.148	24.989
Nm^3 Biogas/year	18275185	33213175	19744675	4069020	9120985
Energy from biogas/year (MWh)	109651	199279	118468	24414	54725
Installed power potential (MW electric)	5.848	10.62	6.31	1.30	2.91

Totalling data presented in Table 5, we found that using the whole quantity of animal waste, the biogas production potential is ***84423040 m^3 biogas/year***, which contain ***506537 MWh energy***. This energy can be converted into 202614 MWh electricity in CHP units totalling approximately ***27 MW installed power***. It is important to specify that it is impossible to exploit all this theoretical potential and to obtain biogas from the whole quantity of animal waste presented here. Wide spread of the small farms makes the collection and transport of animal waste too expensive and energetically inefficient. Biogas plants are efficient in large farms, accounting sufficient number of animals to provide substrate for a biogas plant of minimal efficiency (e.g. 250 KWel installed power), or in farms where other substrates are available in the proximity (plant residues, food waste, municipal waste etc). However, in Timis County large animal farms are operated, especially swine (from the total livestock of 588471 pigs presented in Table 5, around 300000 pigs are concentrated in large farms). This means that over 50% from the theoretical potential can be easily exploited. We estimate the same situation in cattle and poultry. As for horses, sheep and goats, a large portion of the manure from these animals remains on the field, as pasturing is the main form of farming in these cases. Nevertheless, several intensive exploitations of these animal categories, where manure is collected in the farm are presented in Timis. Biogas plants can be installed in these cases.

Crops residues are generated each harvest season, and represent the second main source of biomass suitable for anaerobic fermentation and biogas production. By drying or ensiling, this biomass, can be available year-around. Although technologies are developed to use crops residues as source for biomass combustion, research data indicate high content of ash and sometimes high humidity, which make this type of biomass more suitable for biogas production, rather than for combustion [10]. By summing data from Table 6, we found that the biogas production potential from crops residues generated in Timis County is of ***490395034 Nm^3 biogas/year***. This quantity of biogas contains approximately ***2942370 MWh energy***, which can be transformed in heat and electricity in CHP units totaling around ***160 MW installed power***.

Table 6. Biogas production potential from crops residues

Main crops	Cereals (wheat, barley, oat, rye)	Corn grain	Oil plants	Vegetables
Plant residues after harvesting (t)	119547	876264	88878	39607
Dry matter (DM, %)	85%	86%	13%	25%
Organic dry matter (ODM, %)	90%	72%	85%	80%
Biogas (m^3/t ODM)	350	820	710	820
Total Potențial– Nm^3 biogas/year	32008709	444917788	6972923	6495614
Energy from biogas/year (MWh)	192052.25	2669506.73	41837.538	38973.68
Installed power potential (MW)	10.24	142.37	2.23	2.07

This theoretical potential will probably never be totally used. The main reason is the spread of surfaces of crops, the costs and energy involved to collect, transport and store the crops residues around the year, to have a continue production of energy.

Organic municipal solid wastes (OMSW) represent an important source of organic matter and in several countries this potential is exploited in large part by processing organic solid wastes collected from the population in biogas plants. The main condition for processing municipal organic wastes in biogas plants is the existence of a sorting collection system of municipal solid wastes. Organic wastes should be collected separately in order to be processed in equipments for biogas production. As presented in table 3, in Timis County around 191500 tons of organic wastes are collected annually. Considering a biogas production potential of 120 m^3 / t organic waste, we conclude that around ***23 million m^3 biogas*** can be produced annually from OMSW generated in Timis County. This biogas contains approximately ***138000 MWh energy***, which can be transformed in heat and electricity in CHP units totaling over ***7 MW installed power***. This potential can be totally used, simply by implementation of an efficient separation system of organic waste from the total MSW. Another important aspect to be considered in this case is the continue availability of this substrate and the very high probability of increasing quantity of OMSW collected in the future.

Wastewater treatment plants - WWTP (both municipal and industrial) provide sludge, which is the only substrate currently processed and used for biogas production in Romania. In Timisoara, for example, a brewery applies anaerobic fermentation of wastewater resulted in beer processing with biogas production. This biogas is burned in a boiler to produce steam used in beer production process. As previously mentioned, in Timis County approximately 296 tons of sludge (D.M.) results yearly from WWTP, with a content of 90% organic matter. This organic matter can be converted in 267000 m^3 biogas which contains approximately ***1762 MWh energy***, which can be transformed in heat and electricity in CHP units totaling around ***94 KW installed power***. These figures show a reduced potential, but this potential can be easily and totally used by equipping all WWTP with biogas technology.

Other important source for biogas production is the wasted surface of arable land, which is left uncultivated. This accounted in 2010 around 80000 ha in Timis County. This unused potential can be exploited by cultivating energy crops on this surface. If we consider corn silage as energy crop for biogas production, by cultivating the mentioned surface, and obtaining an average production of 35 tons/ha, 2 800 000 tons of corn silage can be produced. Previous research [2, 8, 14, 15] established that in average 170 m^3 of biogas with 60% methane content can be obtained from 1 tonne of corn silage. Our calculations, using these data and applying the calculation model presented previous, indicate a biogas production potential of ***476 million m^3*** of biogas, containing ***2 856 000 MWh energy***, which can be transformed in heat and electricity in CHP units totaling over ***150 MW installed power***. This potential is hard to be used, as the uncultivated arable land is widely spread and transportation costs will decrease the efficiency of the process.

Industrial waste is another important source of organic matter for biogas production (food industry, cellulose and paper, biofuels industry etc). Unfortunately, we couldn't find clear and reliable statistical data to calculate this potential.

We didn't take into calculation in this study the biogas production potential from special production crops, or energy crops cultivated on agricultural surfaces actually used to produce crops for food or feed purpose. If we sum the previously obtained data, we find that around 600 million m^3 of biogas can be produced only from agricultural and municipal waste (Table 7). The total amount of energy contained by this biogas (3.5 TWh) can be transformed in CHP units into 1.4 TWh electricity and 1.4 TWh thermal energy. If we add the biogas produced from uncultivated arable land, the amount increase to over 1 billion m^3 (see Table 7). This biogas (6.4 TWh) can be transformed in CHP units into 2.56 TWh electricity and 2.56 TWh thermal energy.

Table 7. Total biogas production potential from wastes in Timis County

Specification	Nm^3 biogas/year	Energy from biogas/year (MWh)	Installed Power (MW electric)
Animal waste	84423040	506537	26.99
Crops residues	490395034	2942370.2	156.91
OMSW	22980480	137882.9	7.35
WWTP	26.000	1762	0.1
Total, only from wastes	598065554	3558552.1	191.35
Corn silage from uncultivated arable land	476.000.000	2856000	152.3
TOTAL	1.074.065.554	6414552.1	343.65

Figure 1 indicates the participation ratio of each source of organic substrates to the total biogas production potential. This figure demonstrates the importance of exploitation of agricultural resources for renewable energy production. The main potential for biogas production relay on agricultural sector. The only resource used currently for biogas production, the WWTP sludge represents an infinitesimal part of the whole potential wasted annually in Timis County.

To have a better image of this renewable energy production potential in Timis County, we compared the potential quantity of energy that can be produced from biogas with the energy consumption in this region. Because we couldn't obtain the amount of energy consumed in Timis County in 1 year from the local provider of electricity, we used the numbers representing the annual consumption of energy in the Banat

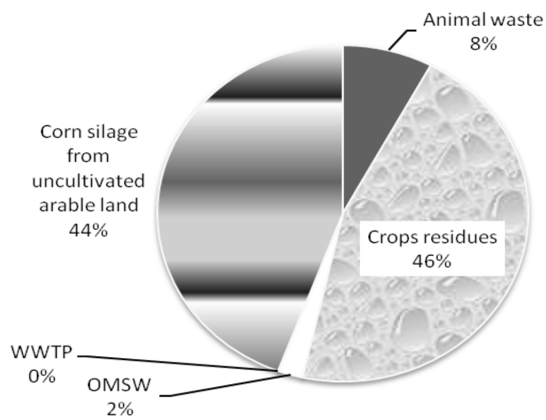

Figure 1. Percentage of biogas production potential of various studied wastes.

electric grid, covering counties Timis, Arad, Hunedoara and Caras-Severin [16]. The outcomes are presented in Table 8.

Table 8. Comparison between energy consumption in West Region of Romania and biogas energy potential

	TWh	Percentage of total
Electric energy consumption in Banat grid (counties Timiş, Arad, Hunedoara, Caraş-Severin)/2009 [16]	3.8	100%
Potential of electric energy production from biogas / waste in Timis County	1.4	36.8%
Potential of electric energy production from biogas/waste + crops from uncultivated land in Timis County	2.56	67.3%

4. Conclusions

Results obtained in this study are quite impressive, even for the authors. Our calculations demonstrates that energetic independency of a community is not a dream and can be possible be using every source of renewable energy. If we look in the most optimistic manner, our data show that organic matter wasted in Timis County can cover one third from the electricity consumption of four counties, and if we add the wasted arable land, the energy from biogas can cover two thirds from the electricity consumption in the four counties mentioned in table 8. Despite the high potential in terms of biogas production from agricultural sources, Romania has among the lowest biogas production in Europe. The main cause is the lack of economic incentives similar to those offered by countries where biogas technology is highly developed. Without a review of relevant legislation, the progress of the biogas sector in Romania will be limited. Furthermore, the development of low-cost technologies available to Romanian farmers will contribute to the development of production of renewable energy from biogas and other biofuels.

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