BIOMASS WASTE GASIFICATION IN ORDER TO REDUCE AIR POLLUTION

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Abstract

Climate change is a major challenge of our times, described as a complex area in which we must improve the knowledge and understanding to take the most appropriate measures, in order to minimize the effects and, if possible, to restore climate equilibrium [1].
Due to energy crisis, research was oriented towards finding new possibilities to produce low cost energy with minimum environmental impact. One of the most important ways to produce green low cost energy is by converting residual biomass into energy by transforming biomass into biogas through anaerobe digestion or through coincineration with solid fuels[2, 3].

This paper presents the results of two case studies developed in order to calculate the pollution reduction by transforming biomass into energy through biogas production or coincineration. First case study aims to estimate the emission decrease of greenhouse gas by using anaerobic digestion of biomass waste, resulting biogas and sludge. Biogas can be used as an alternative source of energy and sludge may be used as a soil amendment and fertilizer in agriculture. It has been observed a reduction of 53-73% of CO_2 emission after using biogas to produce electricity[5]. The sludge from the biogas station corresponds qualitatively to fertilize agricultural land and can lead to a corresponding reduction in CO_2 equivalent to produce 902.4t of NH_4NO_3. The second case study was developed in order to establish the level of CO_2 emission reduction by using the biomass with coal in the energy industry [8,9]. It is also observed a reduction of CO_2 emissions correlated with the amount of biomass used for coincineration. Both case studies indicate a high reduction of greenhouse gas after using biomass for direct or indirect production of energy.

Keywords: anaerobic digestion, biogas, air pollution, biomass

Introduction

As a result of the global energy crisis and for the reduction of greenhouse gas, research into new energy sources have revealed new possibilities of superior utilization of biomass residues; In two case studies , we demonstrate a reduction in greenhouse gas emissions by using biomass to produce energy directly or indirectly

In the first case study, anaerobic digestion biogas obtained from biomass waste is used as an alternative energy source and mud, depending on the solids content, is used as fertilizer in agriculture [1].

Anaerobic digestion is a natural process of decomposition of organic matter in organic matter with a simple molecule and a gas mixture containing CH_4 , CO_2, H_2, N_2, H_2S. The process is carried out in the absence of oxygen under the metabolic influence of anaerobic bacteria. The resulting gas mixture is called biogas and is considered an unconventional (alternative) source of energy.

The second case study was developed in order to determine the level of reduction of CO_2 emissions by using biomass as fuel in combination with coal in the energy industry. It results a reduction in CO_2 emissions related to the amount of biomass used for co-incineration. In order to assess the reduction of CO_2 emissions when using biomass in coal incineration process we have calculated emission factors and related CO_2 emissions. The addition of biomass in both slag samples and coal samples leads to an increase in the carbon content and calorific value proportional to the percentage of biomass added. For the biomass-coal mixture it is also observed a reduction in sulfur content and the amount of ash.

Experimental part

1. Quantification of reducing greenhouse gas levels by using biogas.

A biogas plant that uses as feedstock the waste from poultry slaughtering and vegetal mass produces biogas, which is then used as fuel for two power generators. The resulted sludge is used as fertilizer for agricultural soils.

Remnants of slaughter (viscera, bones, heads, etc.) are collected automatically from the production units by a vacuum transport installation and are carried continuously by a high-capacity pump into a tank. The blood is collected separately in a 3 m^3 tank where it is sent through a pneumatic system to the biogas plant.

At the biogas plant, the debris is shredded and stored in a tank from where it is taken with high-capacity pumps and input into two 10 m^3 sterilisers [2].

After sterilization, the debris is pumped into the two digesters with a capacity of 3000 m^3 each; here it is produced the largest amount of biogas. The remaining digestate passes free to a postdigestor of 3000 m^3 capacity. All three tanks of 3000 m^3 each (two digesters and the postdigestor) have a flexible cover that allows the accumulation of biogas produced at the top.

Another feedstock for the biogas plant is the primary sludge resulted from the wastewater treatment of the sewage collected in the entire base (site).
To optimize the biogas yield, the biogas plant was designed to use and take other feedstock that is used in biogas production: green mass, fruit and vegetable scraps, waste products from brewing, oil and dairy industries, manure, and so on.
Because the feedstock inputs from other industries are not safe, the biogas station was equipped with a high capacity installation for vegetal mass (corn silage, fruit and vegetable scraps, other vegetal debris). The plant is designed to dose the vegetal mass according to the influx of debris from the slaughterhouse.

Calculation of CO_2 emission reduction
The reduction of CO2 emissions corresponding to the energy generated by using biogas was evaluated in two ways:
a) factual, from data obtained in 2012;
b) theoretically, by calculation from the mass of biomass and its general characteristics.

a. Calculation of CO_2 reduction using data from 2012
Slaughterhouse capacity, expressed in t/day at an operating mode of 16 hours/day:
12000 heads/hour x 16 hours x 2kg/cap = 384 t poultry meat (as live)/ day x 250 days/year = 96000t poultry meat (as live)/year
384 tons of poultry meat (as live)/ day x 75% = 288 tons carcass / day x 250 days/year = 72000 tons carcass /year.
Mass of slaughter waste for biogas = 96000t - 72000t = 24000t/year
The total amount of feedstock for biogas: 47500t (fats and other waste, slaughterhouse waste, corn) [3]
Electricity generated from biomass: 18 200 MWh
Specific consumption of electricity: 260-417 kWh / ton carcass, on average 340kWh / t carcass
Energy consumption/year = 340kWh / t carcass x 72000 t / year = 24480 MWh
CO_2 emission reduction = 18000 x Fe x 100/24480 x Fe = 18000 x 100/24480 = 73,5%

b. Estimated by calculating the CO_2 emission reduction
Total waste: W (t)
Total Organic / Volatile Solids: VS = 50%, of which
Biodegradable organic fractions approx. 66% of VS = 0.33 x W
The average efficiency of digestion = 60%
The volume of biogas obtained: B (m3) = 0.80 m3 /kg of VS = 0.80 x 0.60 x 0.33 x W x1000 = 158.4 x W
Calorific value of biogas = 5000 kcal/m3 (medium)
Renewable energy (kWh) = B x 5000/860 = 921 x W
Potential generated power (kW) = 921 x W / 24 = 38.4 x W [4]
Conversion efficiency = 30%
Generator power (kW) = 11.5 x W

Energy from biomass: 47500t x 11.5 = 546,250 kW = 546 250 x 24/1000 = 13.110 MWh
CO_2 emission reduction = 13110 x Fe x 100/24480 x 13110 x Fe = 100/24480 = 53.5%
CO_2 emission reduction by using sludge as fertilizer in agriculture
Annually, the biogas plant produces about 4200t of sludge that, due to its physico-chemical properties, can be used to fertilize the soil as required by Order no. 344/2004 for the approval of the technical standards for environmental protection and, in particular, for the soil, when sewage sludge is used in agriculture.
Sludge contains: 7.52% nitrogen, 1.28% phosphorus, 0.68% potassium and 30.8% organic carbon [5].
Mass of nitrogen: 4200t x 0.0752 = 315.84 t corresponding to 902.4t NH_4NO_3

2. Use of biomass as a renewable source of energy in the energy sector

We have analyzed various samples of coal, biomass, coal-biomass blends, ash and slag, slag mixed with biomass, used in various industrial plants within the energy sector [6] as per Table no. 1.

Table no. 1 Samples used for experiments

Samples	
C1-Coal (lignite)	K2-ash
C2-Coal (lignite)	K3-ash
C3-Coal (lignite)	M1-33%B+67%S
109 B-Biomass	M2-40%B+60%S
110 B-Biomass	M3-60%B+40%S
Z1-Slag	CB1-5%B+95%C
Z2-Slag	CB2-10%B+90%C
Z3-Slag	CB3-17%B+83%C

The samples were analyzed according to specific analysis of solid fuels [7,8]:

- Moisture (Wii,%) according to SR 5264:1995
- Hygroscopic humidity (Wih,%) according to SR 5264:1995
- Total Moisture (Wit,%) according to SR 5264:1995
- Ash (Ai,%) according to ISO 1171:2010
- Elemental analysis (TCI High Heels, Si, Ni,%) according to ASTM D 5373:2008, ISO 10694:1998, ISO 351:1996
- Upper and lower calorific value (QIS, QII, kcal / kg kJ / kg) according to ISO 1928:2009

Recalculation of analysis results in different states (initial, anhydrous) was carried out in accordance with STAS 398/92 and the results are presented in Table no. 2.

Tabelul no. 2 Analysis results

Proba	W_i^i	W_h^i	W_t^i	A^i	S_t^i	C^i_t	$C^i o$	H^i	N^i	O_s^i	Q^i_i	Q^i_i	TOC^{anh}	Fe (C^i_t)	Fe (C^i_o)
	%									Kcal/kg		kJ/kg	%	t CO_2/TJ	
C1- Coal	34.44	7.36	41.80	20.56	1.89	22.41	17.06	2.81	0.81	2171	1779	7448	29.31	110	84
C2- Coal	35.05	7.64	42.69	21.31	1.56	21.79	17.30	2.60	0.69	2141	1754	7346	30.19	109	86
C3- Coal	34.78	7.39	42.17	21.54	1.58	22.03	17.12	2.60	0.72	2161	1778	7444	29.60	109	84
109B-Biomass	39.00	3.74	42.74	0.61	0.01	30.01	-	3.92	0.09	2927	2471	10346	-		
110B-Biomass	39.07	4.25	43.32	0.54	0.01	29.81	-	3.88	0.10	2915	2458	10291	-		
Z2- Slag	35.71	1.11	36.82	-	0.48	9.82	9.08	0.23	0.56	1214	987	4131	14.37		
Z3- Slag	35.54	1.24	36.78	-	0.46	9.34	8.95	0.20	0.56	1211	985	4125	14.15		
K2- Slag	0.00	0.68	0.68	-	0.00	2.16	0.61	0.00	0.00	-	-	-	0.61		
K3-Ash	0.00	0.53	0.53	-	0.00	3.14	0.42	0.00	0.00	-	-	-	0.42		
M1-33% B +67% S	36.80	2.35	39.15	35.35	0.31	15.50	11.66	1.15	0.50	1471	1182	4947	19.16		
M2-40% B +60% S	37.03	2.20	39.23	32.83	0.28	17.15	12.58	1.40	0.47	1606	1303	5456	20.69		
M3-60% B +40% S	37.68	2.41	40.09	21.55	0.20	21.94	16.10	2.93	0.35	2019	1631	6828	26.88		
CB1-5%B +95%C	35.48	8.01	43.49	20.78	1.62	22.13	16.56	2.74	0.75	2145	1746	7312	29.30		
CB2-10%B +90%C	37.63	6.62	44.25	18.82	1.38	22.36	17.20	2.76	0.79	2212	1808	7568	30.84		
CB3-17%B +83%C	37.78	7.72	45.50	17.20	1.23	24.57	18.45	2.81	1.17	2235	1821	7624	33.85		

Results and discussion

Case Study no. 1.

In the case of using biogas to generate electricity the reduction of the emission of greenhouse gases is due to energy saved by using biogas.
Depending on the method of calculation used, the reduction of CO_2 is between 53 and 73% of the CO_2 emission resulted when the electricity required by the industrial consumer is produced.
The sludge from the biogas plant, which can be used as fertilizer, also leads to a reduction in CO_2 emission corresponding to the production of 902.4 t NH_4NO_3.

Case Study no. 2.

From the presented results, one observes that the addition of biomass in both the slag samples and coal samples leads to an increase in carbon content and calorific value proportional to the percentage of added biomass; for the biomass-coal mixture one observes also a reduction in sulfur content and amount of ash.
In these conditions the slag can be reused for co-incineration with biomass.

In order to assess the reduction of CO_2 emissions when using biomass in the co-incineration process, we have calculated the emission factors and the related CO_2 emissions.

The results are presented in Table no. 3 and Figure no. 1.

Table no. 3 Emission factor (Fe) for samples of coal and coal + biomass mixture (CB1, CB2, CB3)

Sample	Fe tCO_2/TJ	Emission, t CO_2 eq
C1-Coal	110	7917
CB1-5%B+95%C	105	7520
CB210%B+90%C	99	7124
CB317%B+83%C	91	6570

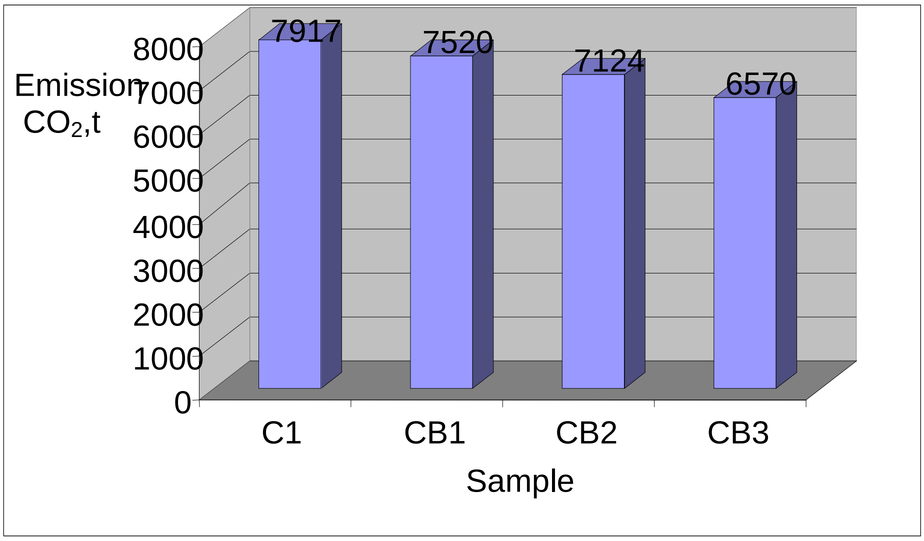

Figure no. 1 CO_2 emissions for coal samples (C1) and coal-biomass mixture (CB1, CB2 and CB3)

When using biomass mixed with coal one observes a reduction in the CO_2 emissions proportional to the amount of biomass used for co-incineration.

CONCLUSIONS

This work presents two case studies where we highlighted the reduction of CO_2 emission by using biomass for biogas production and by co-incineration of biomass mixed with coal.

The first case study is conducted for a biogas plant which uses as feedstock the waste from poultry slaughtering and vegetal mass; the biogas is used as fuel for two power generators and the sludge left is used for fertilization of agricultural soils.

The reduction of CO_2 emissions is evaluated by taking into account the energy generated by using biogas in two situations:

a. based on the data obtained in 2012;

b.calculated based on the mass of biomass and its general characteristics.

Considering the use of biogas for power generation, the reduction of emissions of greenhouse gases is due to the energy saved by using biogas.

In these circumstances, depending on the method of calculation, the reduction of CO_2 is between 53 and 73% of the CO_2 emission resulted when the electricity required by the industrial consumer (slaughterhouse?) is produced.

The sludge resulted from the biogas station, which is qualitatively appropriate for use as soil fertilizer, also leads to a reduction in the CO_2 emission corresponding to producing 902.4 t of NH_4NO_3.

The second case study was devoted to determining the reduction of CO_2 emission by using the biomass mixed with coal for co-incineration in the energy sector.

From the presented results one observes that the addition of biomass in both the slag samples and coal samples leads to an increase in the carbon content and calorific value proportional to the percentage of added biomass. For the biomass-coal mixture one observes in the same time a reduction of the sulfur content and amount of ash [10].

In these conditions the slag can be reused for co-incineration with biomass.

One can also observe a reduction in CO_2 emissions proportional to the amount of biomass used for co-incineration, as presented in Table no. 4.

Table no. 4 Emission factor (Fe) for samples of coal and coal + biomass mixture (CB1, CB2, CB3)

Sample	Fe tCO_2/TJ	Emission, tCO_2 eq	CO_2 emission reduction, %
C1-Coal	110	7917	-
CB1-5%B+95%C	105	7520	5
CB2-10%B+90%C	99	7124	10
CB3-17%B+83%C	91	6570	17

In conclusion we can say that the use of biomass as an alternative energy source produces benefits concerning:

- the reduction of the consumption of fossil fuels in the energy industry, and

- the reduction of the negative environmental impact caused by the storage of certain waste, as well as the CO_2 emissions into the air.

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