EVALUATION OF POTENTIAL BIOGAS PRODUCTION IN SICILY

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Abstract. The aim of the present work is to predict the Sicilian potential biogas production, using the above raw materials. The statistical data about OFMSW, the number of animals bred on medium and large farms and the amounts of by-products of food processing industries have been evaluated, in order to compute the potential biogas production and energy in the nine provinces of Sicily. In Sicily (Italy) 5.05 million inhabitants (2012), living in nine provinces, could produce 0.8 million tons of the Organic Fraction of Municipal Solid Waste (OFMSW) per year. At present only 0.07 million tons (3.17 % ca. of MSW) are actually treated (2010). This fraction would be one of the raw materials inside the mixture usable for biogas production, in a region where no co-digestion plant is nowadays available. About 1.7 million tons of animal manure might be used for biogas generation on medium and big farms. From food industry about 350 thousand tons of organic by-products for anaerobic digestion and biogas production might be collected. The total potential of biogas production in Sicily is 156.9 millions of m^3 that is equal to 941.4 GWh of energy per year. Contribution from animal manure is 402 GWh, from OFMSW – 303 GWh and food industry – 236 GWh. The best possibilities for biogas production are in the provinces of Palermo, Messina and Ragusa, having a potential energy production of 177 GWh, 133.2 GWh and 132 GWh, respectively.

Keywords: biogas, co-digestion, organic fraction of municipal solid waste, animal manure, food industry by-products, energy production

Introduction

The biogas produced in a reactor at the end of an anaerobic digestion process can be used for producing electric and/or thermal energy, in order to contribute to replace fossil-oil based energy sources with renewable ones. Instead the other product of anaerobic digestion (digested substrate) is generally separated into a solid and a liquid fraction. The solid fraction can be used as organic substrate for greenhouse cultivation, while, according to the EU Nitrate-Directive (91/676/EEC nitrate) [1], the liquid fraction can be spread on soils as an organic fertiliser, if its chemical composition is suitable for plant nutrition. This organic fertilizer can be accurately dosed, in order to partly replace and, therefore, minimize the rates of nitrogen mineral fertilizers to be applied.

In Sicily (Italy) 5.05 million inhabitants [2], living in nine provinces, produce 2.15 million tons of Municipal Solid Waste per year, of which 30 % (0.8 million tons ca.) could represent the Organic Fraction (OFMSW), at present only 0.07 million tons of OFMSW (3.17 % ca. of MSW) are treated (according to the Department of Water and Wastes of Sicilian Region, 2010) [3]. This fraction would be one of the raw materials inside the mixture usable for biogas production, in a region where no co-digestion plant is nowadays available. In fact, until now, only one biogas plant using MSW is operating in Sicily, at the landfill of Palermo municipality [4]. Moreover, in Sicily the manure produced on medium and large animal husbandry farms (breeding cows, pigs, poultry etc.) and the by-products of food processing industries (e.g., pomace from olive oil mills and grape marc from wineries) would constitute the mixture usable for biogas production [5].

If a mixture of OFMSW, animal manure and food industry by-products, eventually together with herbaceous energy plants and other raw materials, will be used for biogas production, the biogas yield can be increased [5]. Moreover, the digestate can be accurately dosed and integrated in a fertilisation plan, in order to reduce the application of additional mineral nitrogen fertilizers [6]. Anaerobic digestion results also in a significant reduction of bad smells (up to 80 %) and in a positive change in the composition of odours [6]. Investigations and practical experience show that mixtures of industrial organic wastes with agricultural production ones or plant biomass determine the following benefits: to improve the process of anaerobic digestion, so that the digestate can be enriched with various compounds having properties more suitable for plant fertilization; to increase the biogas yield and, therefore, the biogas plant profitability [7; 8].

In addition, after the anaerobic co-digestion it will be possible to minimise the problems related to the collection of some wastes (e.g. OFMSW, animal manure, sewage sludge, wastes of slaughter

houses), i.e., bad smell (due to the concentration of proteins and sulphuric compounds, that become lower after anaerobic digestion) and high concentration of nitrogen.

Furthermore, the anaerobic digestion process is able to inactivate weed seeds, bacteria (e.g., *Salmonella* spp., *Escherichia coli*, *Listeria* spp.), viruses, fungi and other parasites in the feedstock [9; 10]. Thus, it will be possible to promote the building of co-digestion plants in Sicily, also to contribute to reduce CO_2 emissions and, therefore, global warming.

The aim of the present work is to predict the Sicilian potential biogas production, using the above unmarketable raw materials.

Materials and methods

The statistical data about OFMSW, the number of animals bred on medium and large farms and the amounts of by-products of food industries have been evaluated in this study, in order to compute the potential biogas production, both in terms of biogas volume and energy, in the nine provinces of Sicily.

The potential biogas production from OFMSW (B_{OFMSW}) has been determined according to the equation (1), based on the specific biogas yield (b_w) [11] of this fraction mass unit and the produced mass during a year:

$$B_{OFMSW} = b_w \cdot m_w \quad (1)$$

where b_w – specific biogas yield of OFMSW, $m^3 \cdot t^{-1}$;
m_w – mass of OFMSW, t.

The annual potential energy production from OFMSW (E_{OFMSW}) can be determined according to the following equation:

$$E_{OFMSW} = B_{OFMSW} \cdot e_b \quad (2)$$

where B_{OFMSW} – potential biogas production from OFMSW, m^3;
e_b – energetic value of biogas, depending on the concentration of methane in biogas, $kWh \cdot m^{-3}$.

In order to find the potential biogas production from OFMSW, only the 40 % of the organic fraction of municipal solid waste produced and collected in Sicily was considered to be used for biogas co-digestion production.

The mass of manure produced by each animal type has been computed considering the mass of manure produced by each animal type unit [12] and the number of animals (cows, pigs and poultry). The number of cows, pigs and poultry was derived from the 5th and the 6th General Census of Agriculture (2001 and 2011, respectively) [13; 14].

The potential biogas production (B_m) from animal manure has been determined according to the equation (3), based on the specific biogas yield (b_m) of manure mass unit [12] and the manure mass (m_m) of each animal type:

$$B_m = b_m \cdot m_m \quad (3)$$

In order to compute the potential biogas production from manure, only the manure produced and collected on medium and large farms (having a minimum number of 50 cows or 100 pigs or 1000 poultry units) was considered to be used for biogas co-digestion production.

The annual potential energy production from animal manure E_m can be determined according to the following equation:

$$E_m = B_m \cdot e_b \quad (4)$$

where B_m – potential biogas production from manure, m^3;

The potential biogas production (B_b) from the by-products of food processing industries (e.g., pomace from olive oil mills, grape marc from wine making plants) has been computed using the

equation (5), based on the specific biogas yield (b_m) [5] of each by-product type and the related mass (m_b) [13]:

$$B_b = b_b \cdot m_b \quad (5)$$

The annual potential energy production from the by-products of food processing industries (B_b) can be determined according to the following equation:

$$E_b = B_b \cdot e_b \quad (6)$$

Results and discussion

The total mass of OFMSW, the potential biogas and energy production from this fraction, the manure produced on medium and large animal husbandry farms and the by-products of food processing industries, both in the nine provinces of Sicily and in the whole region, are presented in Table 1.

More than 315 thousand tons of Municipal Solid Waste per year might be dedicated for biogas. About 1.7 million tons of animal manure might be used for biogas generation on medium and big farms. About 350 thousand tons of organic by-products might be collected from food industry for anaerobic digestion and biogas production.

The highest potential biogas production from this mixture is in the provinces of Palermo (29.5 millions of m^3, equal to 177 GWh per year), Messina (22.2 millions of m^3, equal to 133.2 GWh per year) and Ragusa (22 millions of m^3, equal to 132 GWh per year).

Table 1

Sicilian potential biogas and energy production from OFMSW, animal manure and food industry by-products

Provinces	Organic wastes								
	OFMSW			Animal manure			Food industry by-products		
	Mass	Biogas	Energy	Mass	Biogas	Energy	Mass	Biogas	Energy
	10^3 t·y^{-1}	10^6 m^3	GWh	10^3 t·y^{-1}	10^6 m^3	GWh	10^3 t·y^{-1}	10^6 m^3	GWh
Agrigento	26.6	4.3	25.8	57.6	1.2	7.2	47.4	5.0	30.0
Caltanissetta	15.4	2.5	15.0	25.8	1.4	8.4	22.1	2.6	15.6
Catania	75.0	12.0	72.0	180.6	5.1	30.6	31.6	3.0	18.0
Enna	8.6	1.4	8.4	46.2	11.7	70.2	12.7	1.2	7.2
Messina	40.6	6.5	39.0	148.3	14.2	85.2	15.5	1.5	9.0
Palermo	82.1	13.1	78.6	146.6	8.7	52.2	67.6	7.7	46.2
Ragusa	16.4	2.6	15.6	850.5	18.0	108.0	13.2	1.4	8.4
Siracusa	25.1	4.0	24.0	197.6	5.9	35.4	16.4	1.6	9.6
Trapani	25.5	4.1	24.6	74.8	0.8	4.8	124.0	15.4	92.4
SICILY	315.3	50.5	303.0	1728.0	67.0	402.0	350.2	39.4	236.4

The potential energy production from OFMSW, animal manure and food industry by-products, both in the nine provinces of the region and in Sicily, are presented in Figures 1 and 2, respectively.

The highest potential energy production from OFMSW is in the province of Palermo due to a greater number of inhabitants and a more efficient separate waste collection, whereas from food industry by-products it is in the province of Trapani, due to a highest number of food processing industries, as shown in Figure 1. Furthermore, the highest potential energy production from manure is in the province of Ragusa, because of a more intensive animal husbandry.

The potential energy production in Sicily from OFMSW is 303 GWh, from animal manure it is 402 GWh, from food industry by-products it is 236.4 GWh.

The anaerobic digestion of the mixture studied in this work (constituted by OFMSW, animal manure and food industry by-products) would produce 156.9 million m^3 of biogas, that are equal to 941.4 GWh per year.

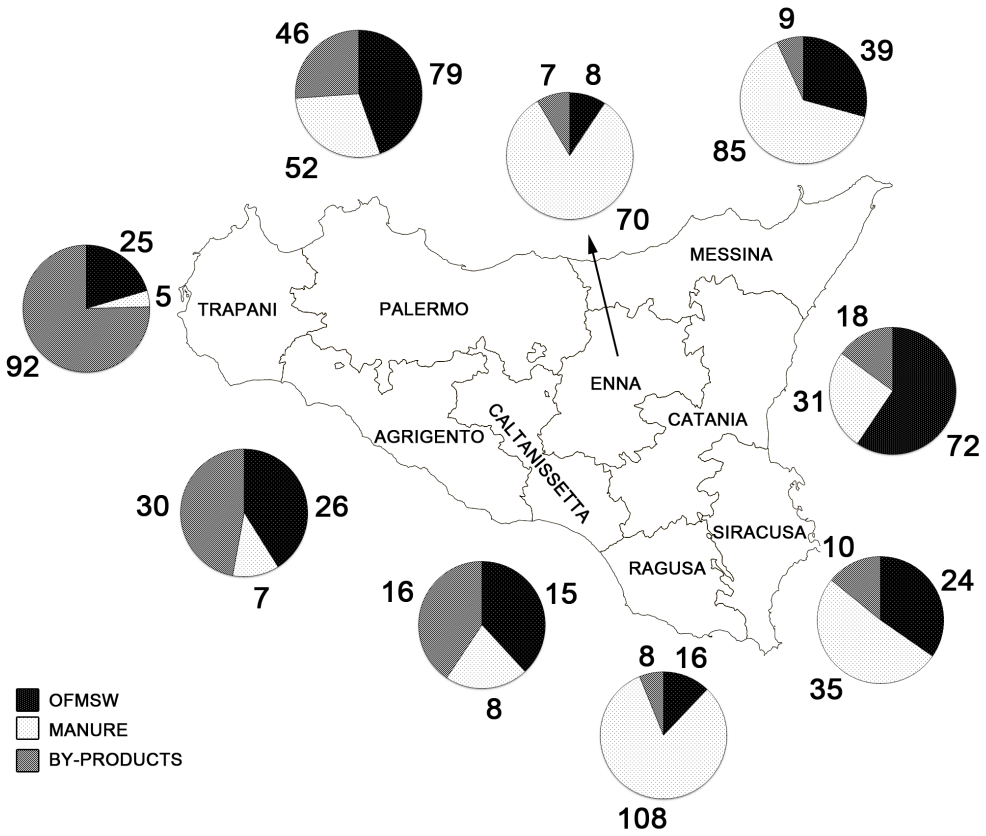

Fig. 1. **Potential energy production from biogas in the nine provinces of Sicily (GWh)**

This mixture, expressed both in terms of biogas volume and energy, is mainly constituted by animal manure (43 %) but also by OFMSW (32 %), and for the remaining part by food industry by-products (25 %), as shown in Figure 2.

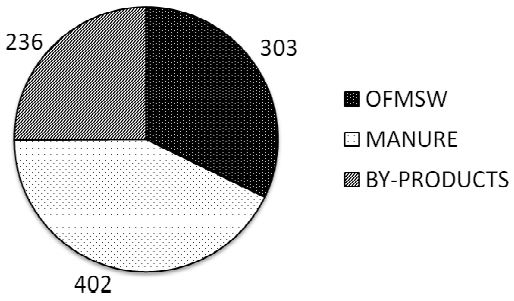

Fig. 2. **Potential energy production from OFMSW, animal manure and food industry by-products (GWh)**

Conclusions

1. The calculated mass of OFMSW, manure and food by-products in Sicily is 315.3 kt, 1728.0 kt and 350.2 kt respectively.
2. The potential biogas production from OFMSW, animal manure and food industry by-products in Sicily is 50.5, 67 and 39.4 million m^3 of biogas respectively.
3. The total potential biogas production in Sicily is 156.9 million m^3 of biogas, which is equal to 941.4 GWh per year.
4. The best possibilities for biogas production are in the provinces of Palermo, Messina and Ragusa, having a potential energy production of 177 GWh, 133.2 GWh and 132 GWh, respectively.

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