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Preliminary Study of Biogas Production from Agricultural Waste in Friuli Venezia Giulia (Nord-East of Italy)

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Abstract

The latest directives of the Energy and Environment Policy of the European Union (EU) established a new framework for renewable sources (Directive EC 28/2009; European Commission, 2009). The Italian Energy Action Plan of 2010 set a target of at least 17% of total energy generated from renewable sources by 2020. In this context biogas from waste and biomass is a potential energy source that can be used for the production of heat, electricity and fuel. The objective of this work was to determine the potential energy production from anaerobic digestion of animal wastes and agricultural residues in Friuli Venezia Giulia (Nord-East Italy).

For an assessment of biogas as an energy source, based on direct conversion by agricultural farms, it is important to establish the amount of the waste. In this study, biogas amount which can be obtained was calculated for all municipalities in the Friuli Venezia Giulia Region (North-East of Italy) by using the number of livestock animals, the cereal area for agricultural residues and also considering various criteria such as the rate of dry matter and availability.
The calculated regional biogas potential is about 204 (N)Mm^3 when using animal waste, straw and corn stalk. The potential of biogas energy equivalent of Friuli Venezia Giulia is about 3 987 TJ (LHV) may be able to replace 2.8% of final energy consumption in Friuli Venezia Giulia (3 339 ktoe) and about 3.3% of the final electricity consumption (864 ktoe) considering an electrical efficiency of 30% with the biogas engine.

Keywords: biogas, animal waste, straw, corn stalk, feedstock.

1 Introduction

The latest directives of the Energy and Environment Policy of the European Union (EU) established a new framework for renewable sources (Directive EC 28/2009; European Commission, 2009). The Italian Energy Action Plan of 2010 set a target of at least 17% of total energy generated from renewable sources by 2020 (European Commission, 2009). In this context biogas from waste and biomass is a potential energy source that can be used for the production of heat, electricity and fuel. Regarding this, Italy took its first steps at the beginning of the 1980s when realisation of biogas production plants from animal waste was essentially aimed at reducing environmental impact in the agricultural sector rather than providing a clean energy source. At present the situation has changed: while the importance of environmental aspects is still fully recognised, there is now the additional need to increase the use of renewable energy sources in rural areas [Tricase et al, 2009].

The number of anaerobic digestion plants in Italy has increased, in recent years, thanks to the old Italian energy law from 244/2007, which provided an all-inclusive feed-in tariff (280 €/MWh for biomass) for electricity production from agricultural biomass, regardless of the feedstock type and the power of the plants. In 2012, some 994 plants in Italy were producing biogas, with a total installed electric power of 750 MW(e) approx. [Colantoni et al, 2011, 2009]. Of these plants, 62% of which were working in co-digestion plants, using both manure with energy crops and agro-industrial residues.

In July 2012, Italy adopted a new regulation for the production of electricity from biomass, making the public support higher if the production of biogas is derived entirely from animal waste and agricultural by-products [Colantoni et al.

2013].

In relation to the biogas potential from agricultural by-products it is important to identify the best farm for the technical and economic convenience of small biogas plants. The objective of this work was to determine the potential energy production from anaerobic digestion of agricultural by-products (animal wastes and agricultural residues) in Friuli Venezia Giulia (Nord-East Italy).

2 Materials and methods

Among The agricultural land area in Friuli Venezia Giulia is 218 443 ha (26.5% of total land area; Giraldi et al 2011, Monarca et al. 2011) with 22 316 agricultural farms (average: 9.8 ha per farm). Only 3 343 farms (15.0%) are raising livestock, including cattle (61.7% of farms), pigs (17.5%), poultry (11.7%), small ruminants (sheep and goats, 8.0%), and rabbits (4.5%). Small ruminants, equines and rabbits were not included in the present analysis. Cattle has the largest share with 89 162 head, 88% of all ruminants. In poultry, 83% are meat chickens (broilers), 8% are laying hens, 6% are turkeys for a total of 6 951 512 pieces. Finally, pigs are present with 216 430 animals (**Error! Reference source not found.**).

Table 1 – The number of livestock farms and total animal numbers for cattle, pig and poultry in Friuli Venezia Giulia (Giraldi et al 2011).

Animal type	Livestock farms	Number of animals	Animals per livestock farm
Cattle	2 050	89 162	43
Pig	586	216 430	369
Equine	582	2 815	5
Poultry	392	6 951 512	17 733
Rabbit	152	670 383	4 410
Goats	141	3 285	23
Sheep	126	10 890	86
Italian buffalo	15	1 449	97
Ostrich	2	251	126

The total number of cattle, pig and poultry with the relative categories was determined using available data for 218 municipalities in Friuli Venezia Giulia (Istat Data Warehouse, 2010). These numbers were then used to estimate the potential production of biogas and its energy content for each of the municipalities. There are several factors which affect the amount of waste and biogas obtainable during livestock operations. These factors include the type and age of animal, body weight, type of breeding, total solids ratio, volatile solids ratio and the availability of waste and biogas yields. The average body weight for the different animal categories was determined using the standards reported in Italian Law 109/2007 (**Error! Reference source not found.**).

In the calculation of the amount of waste, the number of animals in each category (cattle, pigs and poultry) and their sub-categories (age of the animal) were multiplied by the body weight to determine the tons of live weight. The live weight for each category (LW, in ton), was calculated as:

$$\mathrm{LW} = \mathrm{n}^{\circ} \cdot \mathrm{lw} \qquad (1)$$

Where:

n°, is the number of animal in each category;

lw, in tons, is the live weight per head in each animal category.

According to the standards set by Italian Law 109/2007, concerning the agronomic use of livestock effluents, were defined the wet waste per body weight of each type and age of the animals (annual amounts of wet waste were determined in relation to the type of breeding for each category). The livestock operations slurry (liquid material) and manure (shovelable materials) were considered for the waste yield (**Error! Reference source not found.**). The amount of annual slurry (S, in m^3) was calculated as:

$$\mathrm{S} = \sum(\mathrm{LW} \cdot \mathrm{Sb} \cdot \mathrm{Br}) \qquad (2)$$

Where:

LW, in tons, is the live weight for each category;

Sb, in m^3 t^{-1}, is the slurry per unit live weight for the type of breeding in each category;

Br, in %, is the percentage of the type of breeding.

The amount of annual manure (M, in m^3) was calculated as:

$$\mathrm{M} = \sum(\mathrm{LW} \cdot \mathrm{Sb} \cdot \mathrm{Br}) \qquad (3)$$

Where:

LW, in tons, is the live weight for each category;

Mb, in m^3 t^{-1}, is the manure per live weight for the type of breeding in each category;

Br, in %, is the percentage of the type of breeding.

Table 2 – The live weight weight and waste yield of the animals in each category (Istat Data Warehouse 2010).

Animal type	Categor ies	Live weight (kg)	Housing system	Waste yield (m^3 t.l.w.$^{-1}$)	
				Slurry	Manure
Cattle	<1 year	150	Free stall with litter	4	22
			Free stall without litter	22	-
	1-2 years	450	Free stall with litter	10	26.5
			Free stall without litter	26	-
	>2 years	550	Free stall with litter	10	26.5
			Free stall without litter	26	-
	Cows	600	Tie stall with litter	9	35
			Tie stall without litter	33	-
			Free stall with litter	14.5	32
			Free stall without litter	33	
Pig	20-50 kg	35	Partially-slatted	44	-
			Fully-slatted	37	-
			Straw-bedded	3	28
			Concrete floor	64	-
	50-80 kg	65	Partially-slatted	44	-
			Fully-slatted	37	-
			Straw-bedded	3	28
			Concrete floor	64	-
	80-110 kg	95	Partially-slatted	44	-
			Fully-slatted	37	-
			Straw-bedded	3	28
			Concrete floor	64	-
	>110 kg	110	Partially-slatted	44	-
			Fully-slatted	37	-
			Straw-bedded	3	28
			Concrete floor	64	-
	Boar	250	Fully-slatted	37	-
			Straw-bedded	-	31
	Sow	180	Partially-slatted	44	-
			Fully-slatted	37	-
			Straw-bedded	-	31
			Concrete floor	73	-

Table 3 (continued) – *The live weight weight and waste yield of the animals in each category (Istat Data Warehouse 2010).*

	Gilt	100	Partially-slatted	44	-
			Fully-slatted	37	-
			Straw-bedded	-	31
			Concrete floor	64	-
Poultry	Laying hens	1.9	Deep litter with Slatted	0.15	18
			Cage Battery with belt system	0.05	19
			Cage Battery with slurry deep pit	22	-
			Cage Battery with manure deep pit	0.1	17
	Pullets	1	Deep litter	1.2	19
	Broilers	1	Deep litter	1.2	19
	Pharaoh	1	Deep litter	1.7	13
	Goose	6.5	Deep litter	0.9	15
	Turkeys	6.7	Deep litter	0.9	15

The biogas yields from cattle, pig and poultry were calculated according to annual amounts of the organic matter in the slurry and manure waste (
Table 4) (Giraldi et al, 2011; Danieli et al , 2011; Fantozzi et al, 2009). A map of biogas potential production has been produced using GIS-based software. The annual amount of potential biogas (B, in m^3) has been derived from:

$$B = (S \cdot Es) + (M \cdot Em) \qquad (4)$$

Where:
S, in m^3, is the amount of annual slurry;
M, in m^3, is the amount of annual manure;
Es, in m^3 (m^{-3} m^{-3}), is the efficiency of biogas production from slurry;
Em, in m^3 (m^{-3} m^{-3}), is the efficiency of biogas production from manure.

The data of the biogas obtainable during livestock operations were correlated with the agricultural residues. Operational scenarios provided the utilisation of straw and corn stalk. This allowed to identify the technical potential for the biogas production from the agricultural waste in Friuli Venezia Giulia and afterwards evaluate the economic feasibility of biogas plants in relation to different situations of the area (higher public support for the production of electricity when using by-products).

Feedstock	DM content (% a.r.)	Organic DM content (% a.r.)	Specific weight (t/m^3)	Biogas ($Nm^3\ t^{-1}$ Organic DM)	Methane (%)	LHV (MJ/m^3)
Cattle slurry	8.5	6.75	1	230	55	19.6
Cattle manure	18	14.25	0.7	250		
Pig slurry	6.1	4.9	1	355	55-60	20.5
Pig manure	22.5	18.75	0.7	450		
Poultry slurry	19.5	14.9	1	300	60	21.4
Poultry manure	32.25	24.2	0.6	400		
Corn stalks	86	62	0.4	500	54	19.3
Straw	87.5	76	0.04	390	54	19.3

Table 4 – Waste properties and biogas yields of slurry and manure by type of animal (Giraldi et al, 2011; Danieli et al, 2011; Fantozzi et al, 2009).

3 Results

The biogas potential annual production. according to categories and number of animals in designated municipalities in Friuli Venezia Giulia in is presented in *Figure 1*.

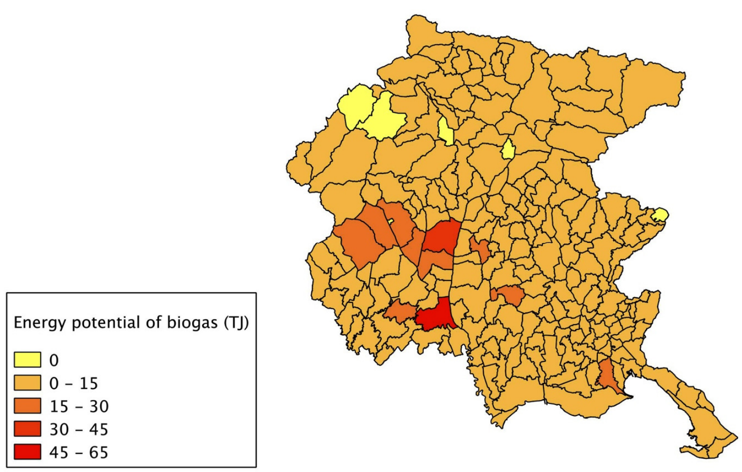

Figure 1 – Distributions of the energy potential of biogas production in Friuli Venezia Giulia

The calculated regional biogas potential is about 55.8 (N)Mm^3 when using only animal waste. where 54% of total energy potential is of cattle origin, 23% from pig and 23% of poultry origin. The potential of biogas energy equivalent of Friuli Venezia Giulia is about 1.128 TJ (LHV) (*Table 5*).

In the map the areas with high potential for biogas production are concentrated in Central-Eastern part of the Region. In particular this area including seven municipalities (San Vito al Tagliamento, Spilimbergo, Maniago, Montereale Valcellina, San Giorgio alla Richinvelda, Aviano and Vivaro) present a high potential due to the presence of intensive farming. The area has the potential of about 14.1 (N)Mm^3 (25% of the regional potential). In particular. San Vito al Tagliamento for pig and poultry, while Spilimbergo for cattle and poultry.

Table 5 – The total biogas production and relative energy potential from animal waste in Friuli Venezia Giulia

Animal type	Biogas production		Energy potential	
	(m^3)	(%)	(GJ)	(%)
Cattle	30 134 202	54	590 630	52
Pig	12 953 589	23	265 549	24
Poultry	12 718 149	23	272 168	24
Total	55 805 940	100	1 128 347	100

The biogas potential from agricultural by-products is about 204 (N)Mm^3. where 28% from animal waste and 72% from agricultural residues (*Table 6*). The energy potential of biogas produced from agricultural by-products may be able to replace the 2.8% of final energy consumption in Friuli Venezia Giulia (3 339 ktoe) and about 3.3% of the final electricity consumption (864 ktoe) considering a electrical conversion efficiency of 30%.

Table 6 – The total biogas production and relative energy potential from agricultural residues in Friuli Venezia Giulia.

Agricultural residues	Area (ha)	Production (t/ha)	By-products (t/year)	Organic content (t/year)	Biogas ((N) Mm^3/year)	Energy potential (TJ/year)	Share of energy potential (%)
Cattle slurry	-	-	733 960	49 542	11	223	5.6
Cattle manure	-	-	526 020	74 958	19	367	9.2
Pig slurry	-	-	694 599	34 035	12	248	6.2
Pig manure	-	-	10 323	1 936	1	18	0.4
Poultry slurry	-	-	10 249	1 527	0	10	0.2
Poultry manure	-	-	126 653	30 650	12	262	6.6
Corn stalks	73 846	5.5	406 153	251 815	126	2 430	60.9
Straw	15 974	4.8	75 877	57 666	22	434	10.9
Total	-	-	2.583.834	502.130	204	3.992	100

4 Conclusion

This work has been a first step in a more complete evaluation of the biogas potential in Friuli Venezia Giulia, which will analyse biogas yields depending on different feedstocks (triticale, straws, agro-industrial waste), plant sizes and logistic solutions, in order to assess the full technical and economic convenience of small biogas plants in the regional area (100-250 kWe). In this context it is important that the public contribution continue to support biogas plants in order to diversify energy production from the agricultural sector. In fact, the establishment of biogas plants can be a solution to support the agri-food sector (milk, eggs, cheese, meat, etc) in Friuli Venezia Giulia.

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