Italian Potential Biogas and Biomethane Production from OFMSW

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Abstract

This work is aimed at predicting the potential biogas and biomethane production, using the Organic Fraction of Municipal Solid Waste (OFMSW), in Italy, where 1388 Anaerobic Digestion (AD) plants (power of 7.4 TWh, equal to 640.4 ktep) are nowadays available.
In order to compute the potential biogas and biomethane production in the 20 Italian regions, the data about OFMSW production in 2010-2013 period have been evaluated.
The Italian production of OFMSW, that was 5.2 million tons in 2013 (18% of MSW), could be used inside bioreactors for producing biogas and digestate, that must be aerobically composted into a biofertiliser. In 2013, the Italian potential biogas production from OFMSW was 739 million m^3, that is equal to 444 million m^3 of biomethane. The highest biogas production from OFMSW was in Lombardy region (143 million m^3), having a potential biomethane production of 86 million m^3. The highest OFMSW production per inhabitant was in Emilia-Romagna region (142 kg). Yet, if OFMSW was 37% of MSW, the potential biogas and biomethane production should be increased: the biomethane production increase would be 486 million m^3, of which the maximum would be in Sicily region.
The biogas produced can be used for generating heat and electricity or upgraded into biomethane, distributed at dedicated stations and useful as biofuel for powering means of transport. This biofuel would replace natural gas, and, therefore, allow a reduction of GreenHouse Gas emissions of 200 g of CO_2 kWh^{-1} (5.5 times lower) and the import of fossil fuels from abroad.

Keywords

Organic waste, Anaerobic Digestion, biofuels, biofertilisers, GreenHouse Gas emissions

Introduction

The Anaerobic Digestion (AD) is the technology that can convert food industry by-products and/or the Organic Fraction of Municipal Solid Waste (OFMSW) and/or sewage sludge into renewable energy inside a bioreactor (Molino et al., 2013). AD process consists of a series of metabolic reactions (i.e. hydrolysis, acidogenesis, acetogenesis and methanogenesis), performed by a wide range of microorganisms in low or no oxygen environments and producing biogas and a digested substratum, called digestate, that must be aerobically composted into a biofertiliser (Comparetti et al., 2013a; Molino et al., 2013).
The biogas produced from AD process contains mainly methane (60% ca.) but also carbon dioxide, hydrogen, hydrogen sulphide, ammonia, siloxane and other substances that may inhibit the AD process itself or cause corrosion problems in plant pipelines or in distribution networks (Karatza et al., 1996; Lancia et al., 1997; Chen Ye et al., 2008).
The biogas produced can be used for extracting biomethane, that can be transferred to the national natural gas distribution grid or distributed at dedicated stations (to be built in the same area of each AD plant) and used as biofuel for powering means of transport. Another option is to transform the above biogas into electric and/or thermal energy inside a CHP

(Combined Heat and Power) plant, in order to contribute to replace fossil-oil based energy sources with renewable ones (Molino et al., 2013; Comparetti et al., 2013b).
Several authors have summarised technologies for biogas purification, aimed at extracting biomethane, by removing hydrogen sulphide, ammonia and siloxane. At the end of this process the biogas still contains hydrogen, carbon dioxide and traces of sulphidric acid and ammonia (<100 ppm), that must be removed from the stream, in order to produce biomethane (IEA, 2007).
The above process of upgrading biogas is a carbon negative balance, because the biomethane replaces the fossil natural gas and the carbon dioxide can be captured and used in industrial processes (Nova Energie, 2015).
OFMSW can be treated together with other organic wastes (co-digestion), e.g. animal manure, sewage sludge and wastes of slaughterhouses, in order to minimise the problems related to the collection of all co-digested wastes, i.e. bad smell (due to the concentration of proteins and sulphuric compounds, that become lower after AD) and high concentration of nitrogen (Comparetti et al., 2012).
The effective management and treatment of biodegradable waste is a topic of increasing importance for municipalities all over the world (Browne and Murphy, 2013).
OFMSW, which is dominated by food waste, is problematic as it is putrescible: it contaminates recyclable materials in combined waste collection methods and releases methane to the atmosphere, when it is deposited in landfill sites. Methane has a Global Warming Potential (GWP) 23 times that of carbon dioxide in 100 years (IPCC, 2012) and significantly contributes to climate change. The Landfill Directive 1999/EC (Directive 1999/31/EC, 1999) has established significant targets for reducing the biodegradable waste conferred to landfills, while the Waste Framework Directive 2008/EC has introduced more demanding waste recycling and energy recovery targets (Directive 2008/98/EC, 2008). Many EU countries have introduced landfill taxes, while some countries, including Germany, have established an outright ban on dumping untreated OFMSW.
The Landfill Directive 1999/EC permits, by 2016, landfills having a maximum storage capacity of 420,000 t/year of biodegradable municipal waste (based on 35% of 1995 amounts), so that alternative waste treatment methods are required for approximately 530,000 t/year of this waste (Directive 1999/31/EC, 1999).
AD is an environmentally effective waste treatment, whose added benefit is energy recovery in the form of biogas (Mata-Alvarez, 2003). The EU Renewable Energy Directive 2009/EC indicates that biomethane from OFMSW has a nominal GreenHouse Gas saving of 80% rather than the displaced fossil fuel (Directive 2009/28/EC, 2009), when it is used as a compressed gaseous biofuel. This saving is higher than other first generation liquid biofuels (Korres et al., 2010).
This work is aimed at predicting the Italian potential biogas and biomethane production, using OFMSW in a country where 1388 AD plants (total power of 7.4 TWh, equal to 640.4 ktep) are nowadays available (GSE, 2015).

Materials and methods

In order to compute the potential biogas and biomethane production in the 20 regions of Italy, the data of ISPRA (Higher Institute for the Environmental Protection and Research) Waste Register about OFMSW production in 2010-2013 period (2015) have been evaluated.
The potential biogas production per year from OFMSW (B_{OFMSW}) was determined according to the following equation, based on the biogas yield (bw) and the mass of this fraction produced per year (m_w) (Marangoni et al., 2013) :

$B_{OFMSW} = b_w \, m_w$ (Eq. 1)

where : b_w is the biogas yield of OFMSW ($m^3\ t^{-1}$);
m_w is OFMSW mass (t).

The potential biomethane production per year from OFMSW (BM_{OFMSW}) was determined according to the following equation, based on the biomethane content of OFMSW (mc_w) and the potential biogas production per year from this fraction (B_{OFMSW}) (Marangoni et al., 2013) :

$BM_{OFMSW} = mc_w \, B_{OFMSW}$ (Eq. 2)

where : mc_w is the biomethane content of OFMSW (%);
B_{OFMSW} is the potential biogas production per year from OFMSW (m^3).

Results

The Italian production of OFMSW, that was 5.2 million tons in 2013 (18% of MSW), could be used inside bioreactors, eventually together with other raw materials, in order to produce biogas and digestate. In 2013, the potential biogas production from OFMSW in Italy was 739 million m^3, that was upgraded into 444 million m^3 of biomethane. The highest biogas production from OFMSW was in Lombardy region (143 million m^3), having a potential biomethane production of 86 million m^3. The highest OFMSW production per inhabitant was in Emilia-Romagna region (142 kg) (Table 1).

Table 1. Italian potential biogas and biomethane production based on the actual OFMSW mass in 2013 (ISPRA, 2015)

N.	Region	Inhabitants (10^3)	MSW (10^3 t)	OFMSW (10^3 t)	OFMSW per inhabitant (kg/person year)	Potential biogas production (10^6 m^3/year)	Potential biomethane production (10^6 m^3/year)
1	Abruzzi	1334	600	119	89	17	10
2	Basilicata	578	207	17	29	2	1
3	Calabria	1981	833	35	18	5	3
4	Campania	5870	2545	618	105	87	52
5	Emilia-Romagna	4446	2780	631	142	89	54
6	Friuli-Venezia Giulia	1229	546	131	107	19	11
7	Lazio	5870	3160	279	47	39	24
8	Liguria	1592	890	54	34	8	5
9	Lombardy	9973	4595	1012	101	143	86
10	Marche	1553	764	196	126	28	17
11	Molise	315	124	8	27	1	1
12	Piedmont	4437	2004	382	86	54	32
13	Apulia	4090	1928	133	32	19	11
14	Sardinia	1664	742	194	116	27	16
15	Sicily	5095	2391	167	33	24	14

16	Tuscany	3751	2234	370	99	52	31
17	Trentino-Alto Adige	1052	495	122	116	17	10
18	Umbria	897	470	88	98	12	7
19	Valle D'Aosta	129	73	5	42	1	0
20	Veneto	4927	2213	662	134	94	56
	Italy	**60783**	**29595**	**5224**	**86**	**739**	**444**

Yet, if OFMSW was 37% of MSW, as it should be, the potential biogas production would be 1550 million m^3 (Table 2), that is similar to 1330 million m^3, estimated by Marangoni et al. (2013). Therefore, the MSW transferred to landfills would be reduced by 19% and also this amount could be converted into biogas and digestate.

Table 2. Italian potential biogas and biomethane production based on a theoretical OFMSW mass in 2013, that should be 37% of MSW (ISPRA, 2015)

N.	Region	Inhabitants (10^3)	MSW (10^3 t)	OFMSW (10^3 t)	OFMSW per inhabitant (kg/person year)	Potential biogas production (10^6 m^3/year)	Potential biomethane production (10^6 m^3/year)
1	Abruzzi	1334	600	222	166	31	19
2	Basilicata	578	207	77	133	11	7
3	Calabria	1981	833	308	156	44	26
4	Campania	5870	2545	942	160	133	80
5	Emilia-Romagna	4446	2780	1029	231	146	87
6	Friuli-Venezia Giulia	1229	546	202	164	29	17
7	Lazio	5870	3160	1169	199	166	99
8	Liguria	1592	890	329	207	47	28
9	Lombardy	9973	4595	1700	170	241	144
10	Marche	1553	764	283	182	40	24
11	Molise	315	124	46	146	6	4
12	Piedmont	4437	2004	741	167	105	63
13	Apulia	4090	1928	713	174	101	61
14	Sardinia	1664	742	275	165	39	23
15	Sicily	5095	2391	885	174	125	75
16	Tuscany	3751	2234	827	220	117	70
17	Trentino-Alto Adige	1052	495	183	174	26	16
18	Umbria	897	470	174	194	25	15
19	Valle	129	73	27	209	4	2

	D'Aosta						
20	Veneto	4927	2213	819	166	116	70
	Italy	**60783**	**29595**	**10950**	**180**	**1550**	**930**

Also the difference between the potential biomethane production from the theoretical OFMSW (37% of MSW) and that from the actual OFMSW was computed for each region of Italy (Fig. 1).

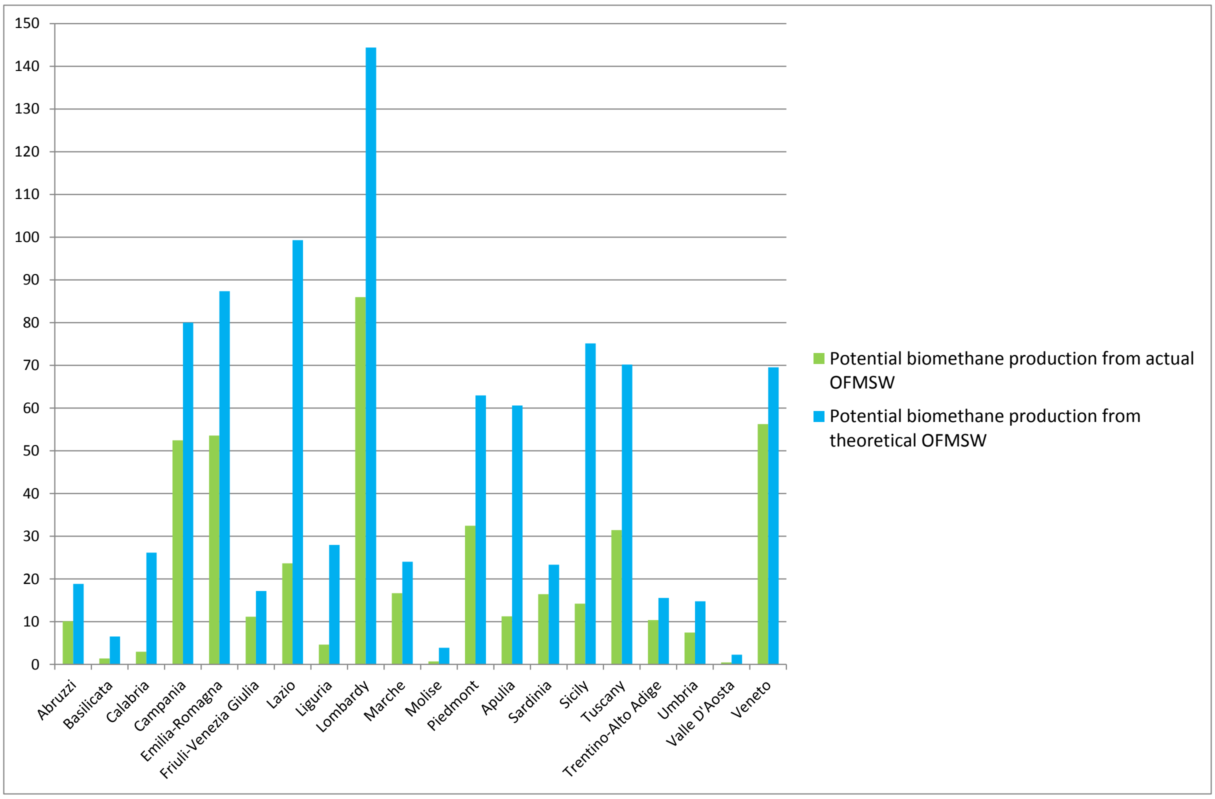

Figure 1. Potential biomethane production based on the actual OFMSW mass in 2013 and that from the theoretical OFMSW mass (37% of MSW) for each region of Italy (10^6 m^3/year)

The potential biomethane production should be increased by 486 million m^3 for the whole Italy, while Sicily resulted the region having the highest possible increase (61 million m^3) (Fig. 2).

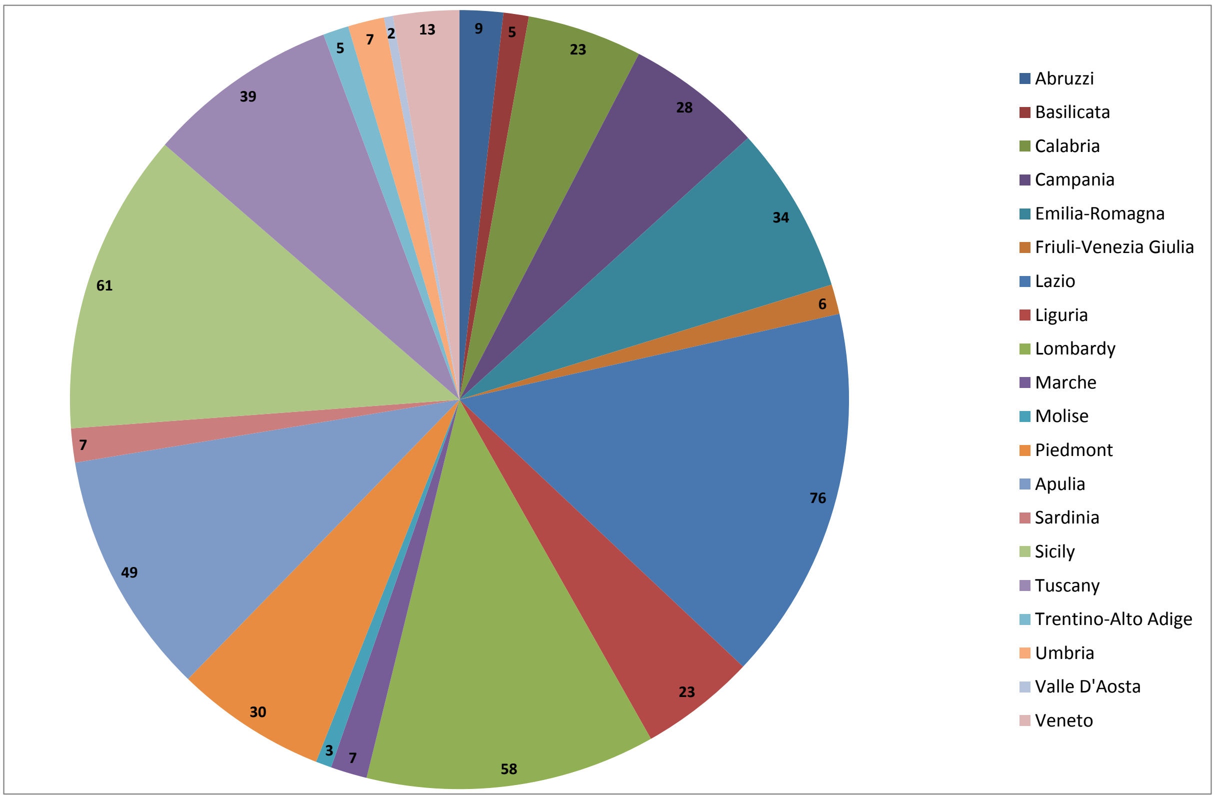

Figure 2. Difference between the potential biomethane production based on the theoretical OFMSW mass (37% of MSW) and that from the actual OFMSW mass in 2013 for each region of Italy (10^6 m^3/year)

Conclusions

The results of this work, showing the possibility of highly increasing the Italian potential biogas and biomethane production through the AD process of organic wastes, e.g. OFMSW, must be included in the perspective of achieving the targets of EU policies about waste, energy, environment and climate.

In fact, the EU Directive 2003/55 has authorised the connection to the natural gas grid: it is possible to inject biomethane, that is a refined biogas having a methane concentration higher than 95% and a quality comparable to that of natural gas. In order to produce pipeline quality biomethane starting from the biogas generated through AD process, it is needed to remove water, sulphur compounds, halogenated organic molecules, carbon dioxide, oxygen and metals (Molino et al., 2013).

Among the possible applications of biogas, if it was upgraded into biomethane, this biofuel would replace natural gas and, therefore, allow a reduction of GreenHouse Gas emissions of 200 g of CO_2 kWh^{-1} (5.5 times lower) and the import of fossil fuels from abroad (Marangoni et al., 2013) for transportation and network applications (Molino et al., 2013).

Several authors have shown that the production unit cost of biogas is 8-10 €cents/m^3 (depending on the organic matter source), while the upgrading cost is 7-8 €cents/m^3, so that the total cost for producing biomethane compressed into the gas grid at 30 bar pressure is 20-22 €cents/m^3. The Italian market price of natural gas, fixed by the National Authority for the Electrical Energy and Gas Use, is equal to 40 €cents/Nm^3 (referred to January 2010) and, therefore, justifies the industrial feasibility of the above process (Molino et al., 2013).

Following the Decree of the 5th December 2013 of the Italian Ministry of Economic Development (2013) about the ways to promote the injection of biomethane into the natural gas grid, this biofuel will play a paramount role in the fuel market in the next five years.
Moreover, as a poor energy balance is associated with many first generation liquid biofuels (e.g. rape seed biodiesel) and the public concern towards biofuels displacing food production is increasing, the concept of using biomethane from organic wastes as a biofuel is very attractive (Mata-Alvarez, 2003; Directive 2009/28/EC; Korres et al., 2010).
Furthermore, fossil fuels are limited resources, concentrated in a few geographical areas of the Earth. This generates, for the countries outside these areas, a permanent state of dependency on imported energy. Most European countries are strongly dependent on fossil fuels, imported from regions rich in fossil fuel sources, e.g. Russia and the Middle East. The development and implementation of renewable energy sources, such as biogas from AD, based on national and regional biomass, will increase the security of the national energy supply and reduce the dependency on imported fuels.
Fighting against global warming is one of the main priorities of European energy and environmental policies. The production and use of biogas from AD has the potential to comply, at the same time, with all the three main goals of the EU climate and energy package for 2020: to reduce GreenHouse Gas (GHG, e.g. CO_2) emissions by 20%; to improve energy efficiency by 20%; to generate 20% of energy consumption from renewable energy sources. A major part of renewable energy will be produced from European agriculture and forestry, through biomass conversion into gaseous, liquid and solid biofuels (Comparetti et al., 2013a).
In this perspective politicians should promote the valorisation of organic wastes (e.g. OFMSW) through AD process. In fact, whether OFMSW was anaerobically digested, it would highly reduce the amount of this waste that is nowadays aerobically composted or, even worse, landfilled (Comparetti et al., 2013c).
If the Italian towns, that support a high cost for OFMSW transportation to landfills or composting plants and the subsequent treatment, would implement AD, could achieve a high saving. At the same time the environmental benefits for all citizens would be the reduction of GHG emissions, as well as soil and ground water pollution by leachate.
The limitation of implementing the results of this work is "ecomafia", that is the mafia involved in environmental business and, therefore, controlling the waste management. The "criminal systems" (as defined by the judge Roberto Scarpinato) are complex illegal networks including policy makers, entrepreneurs, professionals and traditional mafia men. Therefore, a cultural change is needed, firstly in citizens and secondly in policy makers, entrepreneurs and professionals, in order to optimise the separate waste collection and the subsequent recycling, as well as valorise OFMSW through biogas and digestate production (Comparetti et al., 2014).

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