Environmental Engineering and Management Journal October 2019, Vol. 18, No. 10, 2163-2169
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

BIOMASS EXPLOITATION FOR ENERGY SUPPLY AND QUALITY COMPOST PRODUCTION. AN EXEMPLARY CASE OF CIRCULAR ECONOMY IN THE NORTH EAST OF ITALY

Veronica Novelli*, Paola Geatti, Luciano Ceccon, Sara Gratton

Department of Economics and Statistics, University of Udine,
Via Tomadini, 30/A, 33100 Udine, Italy

Abstract

The goal 12 of the 2030 Agenda for Sustainable Development takes into consideration the responsible consumption and production in the perspective of circular economy. The agri-food sector is more actively involved in these initiatives, because it offers the possibility to exploit waste and by-products, by adopting suitable biotechnologies. Such processes can be carried out either under aerobic conditions, for the production of compost, or anaerobically, for the production of biogas. In this work the case of a plant managed by Desag Ecologia, located in the municipality of Sedegliano, in the North-East of Italy, is presented. The plant started up in June 2016. Its main activity consists in exploitation of the organic fraction of municipal solid waste and urban forestry green waste coming from separate waste collection. The basin of provenance of collected materials consists not only of the province of Udine, but also of other areas of the Friuli Venezia Giulia region and other northern Italian regions. The plant ensures the production of both biogas (used in a cogeneration installation for producing electricity and heat) and quality compost, which can be used in agriculture, after submission to physico-chemical analyses to verify the end-of-waste status. In this way, the reduction of waste disposal in landfill is ensured. Thermal energy is partially recovered for the production of hot water to heat the anaerobic digester, the leachate collection tank and the plant rooms. Approximately 10% of electricity is self-consumed for the needs of the anaerobic facility, the remaining amount is fed straight into the public electricity network.

Key words: biogas production, cogeneration, compost production, integrated anaerobic-aerobic plants, organic waste management

Received: February, 2019; Revised final: July, 2019; Accepted: August, 2019; Published in final edited form: October 2019

1. Introduction

The European Commission has adopted the revised Best Available Techniques (BAT) conclusions for waste treatment, published on August 17th, 2018, giving to the national authorities the guidelines for technical installation. The document contains BAT conclusions for the most common waste treatments, including mechanical, biological and physical-chemical treatments and treatment of water-based liquid waste (EU Decision, 2018).

The Directive 2009/28/EC fixed the guidelines for waste management, recycling and recovery, in order to reach a separate waste collection (SWC) of 50% by 2020 (EC Directive, 2009). According to the "Report on Municipal Solid Waste (MSW), 2017 Edition", (ISPRA, 2017), Italy is not so far from this target, even if the situation is different among the regions. In 2016, Italian production of municipal solid waste (MSW) was 30.1 million t, with a 2% increase in respect of 2015. The percentage of separate waste collection (SWC), calculated as the ratio between the amount of materials collected by separate waste collection and the amount of materials collected as unseparated MSW x 100, was 52.5%, with an increase of 5 points if compared with 2015.

* Author to whom all correspondence should be addressed: e-mail: veronica.novelli@uniud.it

SWC per capita was 261 kg at the national level, 328 kg in the North of Italy (+38 kg more than in 2015), 266 in the Centre (+28 kg more than in 2015) and 169 in the South (+20 kg more than in 2015). From 2011 to 2016, SWC variation was 62 kg per capita. In 2016, in the Friuli Venezia Giulia (FVG) region, in the North-East of Italy, SWC was 67.1%, with an increase of 6.7% in respect of 2015.

The EC Communication 2015/614/EC promoted SWC in order to decrease landfill disposal, by introducing economic incentives for technological solutions (EC Communication, 2015). In Italy, the Ministerial Decree of June 23, 2016 fixed exact dispositions for plants fed by biomasses, biogas and sustainable bio-liquids production (MD, 2016). According to the LD, (2003), biomass is the biodegradable part of the residues of forest sector, agricultural and food industry sectors, zoo-technical sector, organic waste (residues of green and scraps of food)

Every year, the report on the State of Green Economy intervenes on national and European debate on the sustainability of economic recovery and job occupation. In particular, the General States of the Green Economy 2012 organized a national strategy for the revival of biomass supply chain: "Biomass potential in Italy is very high, but there are many obstacles for its exploitation. It will be necessary to develop the second and third generation of biofuels, the biogas/bio-methane supply chain and the energetic valorization of biodegradable fraction of waste, taking into account the respect for the European hierarchy" (Ronchi and Morabito, 2012).

In 2016, SWC of organic fraction (consisting of the wet fraction of kitchen scraps and of waste coming from the management of gardens and parks and ornamental green) in Italy was 6.5 million t, considering also the quantity destined to domestic composting, which corresponds to more than 220,000 t; an increase of almost 450,000 t (+7.3 %) was observed compared with 2015. Also, in 2016, the plants of mechanical-biological treatment processed, in Italy, more than 10.8 million t of waste, with a 4.4% increase in respect of previous year. About 5.7 million t were recovered in these plants at the end of the process (+ 10% in respect of 2015). Almost 3.4 out of 5.7 million t were addressed to composting plants, about 2 million t to integrated anaerobic/aerobic treatment plants and little more than 249,000 t were worked in anaerobic digestion plants.

In 2016, 326 plants (309 in 2015) were working in Italy. More in particular, 274 plants (263 in 2015) were devoted only to aerobic treatment (composting), 31 plants (26 in 2015) to integrated anaerobic/aerobic treatment (ISPRA, 2017) and 21 plants (20 in 2015) to anaerobic digestion (Bacenetti et al., 2013; Bozano et al., 2012). 26 integrated plants were located in the North, in particular 2 in the FVG region, 2 in the Centre and 3 in the South. In these plants, biogas is produced by anaerobic digestion and compost by aerobic degradation of digestate and other organic waste. The composition of the treated substrate is made up of 69% of wet fraction, 10% of green fraction, 15% of sludge and 6% of other waste: the organic fraction is 91% of the total waste managed by integrated plants (ISPRA, 2017).

Exploiting the bio-waste involves many associated activities: the collecting services, the technical effort for the plant project and realization, the activities for the valorization and the use of compost. The affair volume of the supply chain for the collection-treatment of bio-waste is about 1.8 billion euro/year (ICC, 2018).

The integrated plants, built to control the odorous emissions and to stabilize the biomasses, are constituted of sequential treatment lines to recover renewable energy under biogas/bio-methane form, and to transform the digestate, plus other organic waste, by aerobic treatment, in quality compost for use as fertilizer in the agricultural sector (ISPRA, 2017).

An integrated plant is a sustainable plant, from all the points of view, giving benefits to:

- the economy of the territory, by assuring work to the community and by producing profits (economic and social support for the society);
- the community that is sure that the collected organic fraction is re-cycled (to produce renewable forms of energy and compost);
- the environment from which fewer primary resources are taken, through the use of renewable materials (organic waste); moreover, burning biogas is less polluting for the environment than burning fossil fuels (Arthur et al., 2011). Furthermore, the produced compost is suitable to fertilize fields, when the results of the chemical analyses assure its qualification to be used in the agronomic sector (ICC, 2018).

Biogas composition mostly depends on the type of decomposed material 50–85% CH_4 (methane); 20–35% CO_2; H_2, N_2 and H_2S form the rest (Pastorek et al., 2004; Salomon and Lora, 2009; Vasmara and Marchetti, 2018).

Biogas production can be considered a sustainable process for simultaneous treatment of organic waste and generation of renewable energy (Angelidaki et al., 2018; Mateescu et al., 2008). Biogas is a clean fuel used for heat, electricity and transport (Scarlat et al., 2018). If biogas is used as fuel, it is necessary to remove carbon dioxide to increase the percentage of methane and subsequently its calorific power.

In Europe, considering the national consumptions of natural gas, the contribution of biogas is 4% on average, but it is widely different depending on the country considered, reaching the maximum of 12% in Germany. Germany, United Kingdom, Italy and Denmark are the leader producers (Scarlat et al., 2018). In Italy, the LD (2010a) defined the conditions that must be met by organic waste to stop the waste status at the end of the composting process. As a consequence, three types of qualified amender can be obtained: composted green amender, composted mixed amender and composted amender with sludge, depending on the typology of waste treated (LD, 2010a).

Afterwards, the LD (2010b) defined quality compost as "the product obtained by organic waste composting under specific technic rules, to be adopted by the State, finalized to define contents and use compatible with environmental and health protection and, in particular, to define quality levels".

The aim of this study is to present a successful integrated plant, managed by Desag Ecologia, located in Sedegliano, in the province of Udine, in the North-East of Italy, that contributes to circular economy, by exploiting biomass (household organic and green waste) for the anaerobic production of biogas, and subsequently aerobic production of quality compost.

2. Material and methods

An in-depth analysis of successful projects of waste management in the FVG region allowed to find out a recent plant designed to treat the organic fraction of MSW and green waste on the basis of anaerobic/aerobic digestion: Desag plant, located in Sedegliano, in the province of Udine. For getting eloquent data and information, we visited the plant and interviewed the Chief Executive Officer (CEO) of the facility to collect data and information. Furthermore, some e-mails and calls were necessary to improve information on the characteristics and production aspects of the plant. Data and information collected are presented in Tables 1-5.

3. Case study presentation

Desag Ecologia S.c.a.r.l., founded more than 10 years ago, is a special purpose entity set up with 100% private capital, of which leading private companies are part: De Vizia Trasfer S.p.A. and Sager S.r.l.; De Vizia Trasfer S.p.A. is specialized in heavy lifting and industrial installations assembly sectors, Sager S.r.l. is specialized in integrated waste management. In the case studied, Desag Ecologia signed a concession contract with A&T 2000, ~~a~~the grantor society for the building of a plant for renewable energy and compost production, for a total period of 25 years in a project financing operation where the public authorities require private capitals for the realization of work for public use in accordance with current legislation (Italian Law, 1998). A&T 2000 is a public society founded in 1998, as a natural evolution of an aggregation of municipalities of the province of Udine, with the aim of implementing economic and operational strategies in the field of municipal waste management. At present, it incorporates 50 municipalities and has a catchment area of 200,000 inhabitants.

Within the project financing, A&T 2000 is the grantor subject, that is to say who provides the good, in this case waste. A&T 2000 deals only with ensuring the commodity (waste) at a specific tariff agreed with Desag Ecologia. The construction and operation of an integrated plant of anaerobic digestion and composting were charged to concession holder, Desag Ecologia.

The Desag Ecologia plant is located in Pannellia, in the municipality of Sedegliano, in the province of Udine, in the North-East of Italy; its construction started in 2013 and the plant was put into service in June 2016. A schematic representation of the stages of the production process is given in the Results and discussion section (Fig. 1).

After a first phase of waste acceptance, aimed at selecting only compliant waste, a storage phase follows, in specific inner paved areas, coated with anti-wear anti-acid lining and provided with a liquid conveying system. During these phases, specific measures ensure the least pollutant or odorous emissions leakage. Accepted waste is classified into four categories: organic fraction of municipal solid waste and similar, mowing materials/small wood waste, large wood waste and sludge. Purity of incoming materials is verified by random sample analysis, visual check and bulky waste removal.

The production process starts with a waste pre-treatment phase: waste pass through a machine devoted to bag opening (the machine is also equipped with a system aimed at detecting foreign materials). Large wood waste are subjected to a possible volumetric reduction (chipping).

Anaerobic digestion. Anaerobic digestion is performed in a single-stage, batch feed, dry fermentation way, at 37°C for a duration of 28 days. The plant consists of 8 fermenters, that allow to treat approximately 830 m^3 of mixture. The fermenters are equipped with a heating system installed on the bottom and the walls, which is ensured by the heat recovered by the group of biogas cogeneration. This system allows to maintain the process temperature in fermenters.

The fermenters are uploaded (and emptied after a fixed reaction time) in different days, properly scheduled, in order to ensure continuity to the process and to properly distribute downloading, mixture preparation and material uploading for the following cycle. In order to ensure the conditions of constant moisture and controlled temperature, the leachate generated from biomass is partly collected and sprayed once again on medium in a controlled way.

Biogas Production. Anaerobic digestion process enables to obtain biogas, which is conveyed into two co-generation groups (499 kWe each), for combined heat and electricity production. Before combustion, biogas is submitted to pre-treatments: filtration (on activated carbon), dehumidification (by means of a condenser) and compression at 80 mbar.

The Desag Ecologia plant is equipped with a safety torch, which is activated only in case of the start-up phase or of servicing or failure of the cogenerator, or biogas overproduction. In order to ensure security, in the case that the torch is not sufficient, three emergency chimneys have been set up to ensure immediate leakage of excess biogas. Combustion cogenerative engines are provided both with a system that allows the removal from biogas of sulphur compounds, before introduction in combustion chamber, and with a system for absorbing nitrogen oxides in exhausted gases resulting from combustion.

Composting. Composting of the mixture is carried out inside 8 independent bio-tunnels, isolated from the external environment. The static heap technique is adopted. The bio-tunnels are supplied with a floor aeration equipment, a system of suction of the exhausted air (conveyed to the treatment section in order to eliminate odorous emissions), a device of collection of the process liquids (stored in a devoted tank) and an automatized system of monitoring and control of the process parameters (temperature, moisture, oxygen and carbon dioxide concentrations).

The composting process provides for the previous preparation of the mixture, which is made up by:

- material digested following anaerobic fermentation (about 50% by weight),
- wood waste after chipping and sludge,
- material already subjected to composting and recycled,
- material subjected to primary ageing which is not yet aged,
- intermediate fraction obtained by compost refining, with size between 10-15 and 100 mm,
- possible compost which proved to be not compliant with the criteria established to define the end-of-waste status, and for which the suitability to be recycled in the process has been positively evaluated.

Previous preparation of the mixture is carried out in a covered area in front of the bio-tunnels. The bio-tunnels are loaded in sequence, at pre-defined time intervals, to assure the process continuity and the correct management of the time for the steps of downloading, mixture preparation and material loading for the subsequent cycle. The composting step has the aim of metabolizing the most easily biodegradable materials; it lasts 14 days and is carried out at the temperature of 55°C. At the end of the process, compost is transferred to the primary ageing step, during which the most complex materials are degraded. The primary ageing step lasts 28 days. Then the material is transferred to the area of secondary ageing, located under a roofing, during which the material is periodically turned over. This step lasts 20 days. The final step of refining has the aim of separating possible extraneous fractions which can be present in compost, that is, plastics, iron components and materials with an unsuitable size (greater than 10-15 mm).

On the obtained compost, sampling and chemical-physical analyses are carried out to verify the end-of-waste status. In particular, the employed criterion is the respect of the limits provided for by the enclosure No 2 to the LD 2010a relative to the mixed composted amender (LD, 2010a). In case of not compliance with the aforesaid criterion, compost can either be managed as waste and sent to authorized plants, or recycled in the production process for the preparation of the mixture to be subjected to composting, or used as filtering bed during the bio-filtration process.

Systems for shooting down of emissions into the environment and control systems

The Desag Ecologia plant uses systems under continuous improvement for reduction of diffuse and fugitive emissions. All operations that can generate dust or odor are located inside buildings, in enclosed spaces. The plant is endowed with a suction system, which conveys air to bio-filters which are filled with a mixture of aged compost, bark and sawdust.

The facility is equipped with separate networks of collecting, treatment and discharge of wastewater. The plant is fitted with an automation system, which allows monitoring of process parameters and their dynamic setting, notification of operating faults, activation of correction or emergency procedures, actuation of equipment, plant programming and control.

4. Results and discussion

In this paper, the case of the plant located in the municipality of Sedegliano, in the province of Udine, in the North-East of Italy, is taken into account. The plant is devoted to processing by anaerobic digestion both of the waste coming from separate collection of the organic fraction of MSW and of sludge, and to subsequent composting of the digestate.

In the plant, anaerobic digestion of the raw materials is carried out to produce biogas, which is then transformed into both electric power by two cogeneration engines of the whole potential of 998 kW, and thermal power, used to heat the fermenters in order to keep the process temperature of about 37°C. The potentials of the plant are 31,000 t/year of incoming waste, 3 million Nm^3/year of biogas production and 10,300 t/year of compost production (Table 1).

Table 1. Plant potentials

Incoming waste	99 t/day
	31.000 t/year
Generative groups electric power	2 groups (499 kW each)
Biogas production	3.000.000 Nm^3/year
Compost production	30 t/day
	10.300 t/year

Anaerobic digestion. Anaerobic digestion is carried out after a previous preparation of the mixture, which is made up by:

- 50% of waste represented by the organic fraction of MSW and by green waste (mowing and trimming materials, small wood pieces);
- 50% of digestate produced by the anaerobic fermenters and recycled into the process, to allow the development of a suitable bacterial population.

Percent composition of the mixture for anaerobic digestion is shown in Table 2. In Table 3 the biogas production characteristics are presented.

Table 2. Mixture composition for anaerobic digestion

Material type	*Percentage*
Recycled digestate	50.0
Organic fraction of MSW	42.9
Moving and trimming materials/small wood pieces	7.1
Total	100.0

Table 3. Characteristics of biogas production

Biogas produced per year	3,000.000	Nm^3/year
Production hours	8.760	hours/year
Biogas flow per hour	342	Nm^3/hour

Composting

The percent composition of the composting mixture is shown in Table 4. The following fractions are obtained:

- fraction with a size smaller than 10-15 mm, representing compost, on which plastic suction and separation of iron materials are carried out.

On this fraction, sampling and chemical-physical analyses are carried out to check the end-of-waste status;

- fraction with a size between 10-15 and 100 mm, mainly made up by woodchips, which can be recycled for the preparation of the mixture to be subjected to composting;
- fraction with a size larger than 100 mm, made up by rejected materials which are managed as waste in authorized plants.

The quality compost obtained is certified by Italian Consortium of Composters for use in the agricultural sector. The mass balance flow-chart is shown in Fig.1. The output of materials obtained in 2017 was 3,408 m^3 of biogas, 10,293 t of refined compost, 2,030 t of waste and 2,630 m^3 of leachate.

Table 4. Mixture composition for composting

Material type	*Percentage*
Digestate from the plant	58.5
Not aged compost	30.3
Big wood pieces/waste	6.7
In-between fraction from refining	4.5
Total	100.0

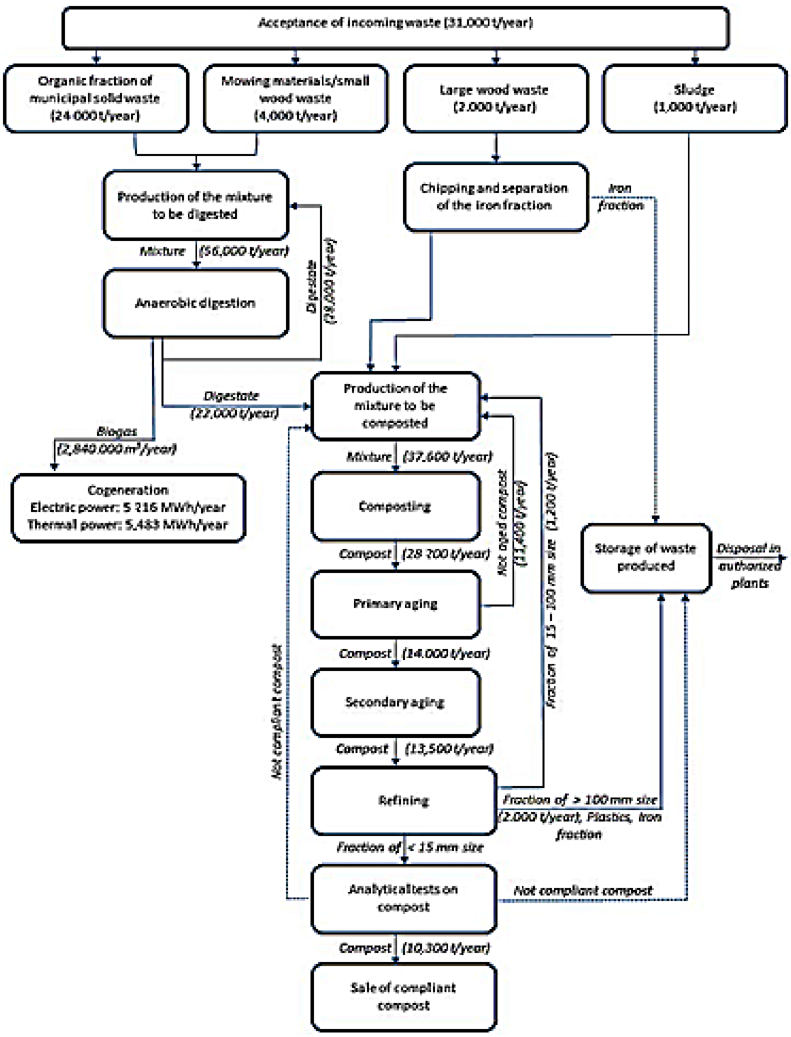

Fig. 1. Mass balance flow-chart for Desag Ecologia plant

At present, 75% of the raw materials treated by the plant comes from the FVG region, while the rest from other basins, but in the future the plant manager will extend SWC to the whole region. In fact, even if the plant started its activity in 2016, the management expects to enlarge the plant potential, by a new area of waste reception, already authorized by the Environmental Integrated Authorization (EIA), and for which other building licenses are required, starting works in 2019. EIA, regulated by the II part of the LD (2006), authorizes the running of plants that carry out activities cited in annex VIII, forcing measures to avoid or reduce air, water and soil emissions (LD, 2006).

Energy balance. The cogeneration engines allow the production of electric and thermal power. About 10% of the electric power obtained is employed for the needs of the plant itself, whereas the remaining amount is distributed by the Enel network. The thermal power obtained is partly recovered by the use of heat exchangers to produce hot water at the temperature of about 85°C. Hot water is employed to heat the digesters, the tank of leachate collection and the technical rooms. The total amount of gas oil employed for collection and transport of raw materials to the plant was calculated on the basis of the average distance covered by the lorries, of the yearly number of transports and of the average gas oil consumption of each lorry, and by considering that the gas oil caloric power is 9.85 KWh/L.

The total amount of gas oil employed for disposal of waste and of part of the leachate produced by the plant was calculated in a similar way. The amounts of energy involved in the management of the plant in 2017 are shown in Table 5.

Table 5. Plant energy balance in 2017

	Thermal and transport power (MWh/year)	***Electric power (MWh/year)***
Production	5.792	5.500
Own consumption	870	550
Amount sold to a third party	-	4.950
External supply	-	3.965
Dissipated thermal power	4.922	
Gas oil employed for collection and transport of raw materials	2.108	
Gas oil employed for waste and leachate disposal	78	

4. Conclusions

The waste management EU policies act in order to reduce the environmental and health impact. Waste production is increasing because population and consumes are growing, so their production in unavoidable, but it is important to improve the technologies for recycling the materials that can be transformed in renewable forms of energy and/or products to be used in different sectors.

To increase the SWC percentage at the national level, by shortening the differences among the Italian regions, is a duty of national policies, by reducing the gap between the collected and the recycled waste.

Anaerobic digestion is a suitable, cheap and simple technology that combines biofuel production with a sustainable waste management, with the aim of controlling also the organic waste smell.

In the future, bio-methane will play an important role because of its versatility in substitution of natural gas; in particular, it can be produced close to the point of use, minimizing the problems related to the transit of gas.

In Italy the integrated treatment plant sector (anaerobic/aerobic) has been constantly growing, involving investments, creating new jobs and generating several positive effects on the national economy.

Desag Ecologia plant efficiency is assured by the clean raw materials used, in particular by the organic fraction coming from separate waste collection and sludge. The plant under examination adopts the best technologies for obtaining biogas and quality compost, consequently the outgoing extraneous materials are very low. Furthermore, the environmental impacts (air emissions and wastewater production) are minimal.

Acknowledgements
The authors contributed equally in idea conception, acquisition of information, data analysis and comment, drafting of the manuscript.

References

Angelidaki I., Treu L., Tsapekos P., Luo G., Campanaro S., Wenzel H., Kouglas P.G., (2018), Biogas upgrading and utilization: Current status and perspectives, *Biotechnology Advances*, **36**, 452-466.

Arthur R., Baidoo M.F., Antwi E., (2011), Biogas as a potential renewable energy source: A Ghanaian case study, *Renewable Energy*, **36**, 1510-1516.

Bacenetti J., Negri M., Cantore A., Cantarella P., Fiala M., (2013), A detailed monitoring of an anaerobic digestion plant in Northern Italy, *Environmental Engineering and Management Journal*, **12**, 109-113.

Bozano P., Nosiglia V., Vitali G., (2012), *Co-Digestion of Biowaste and Commercial Waste with Agricultural Residues – Experiences from Castelleone (Italy)*, 4th Int. Symp. on Energy from Biomass and Waste, Venice Italy, 12-15.

EC Communication, (2015) Communication 2015/614/EC, Closing the loop - An EU action plan for the Circular Economy, On line at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614

EC Directive, (2009), Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, *Official Journal of the European Union*, L 140/16, 05.04.2009, Brussels.

EU Decision, (2018), Commission implementing decision (EU) 2018/1147 of 10 August 2018 establishing best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council, *Official Journal of the European Union*, L 208/38, 17.08.2018, Brussels.

ISPRA, (2017), Report on Municipal Solid Waste (MSW), 2017 Edition, (in Italian), On line at: http://www.isprambiente.gov.it/files2017/pubblicazioni/rapporto/RapportoRifiutiUrbani_Ed.2017_n.272_Vers.Integrale_rev08_02_2018.pdf.

ICC, (2018), Italian Consortium of Composters, Recovery and Recycling of Organic Waste: a Real Example of Circular Economy (in Italian), On line at: http://www.compost.it/attachments/article/1341/Dati%20del%20settore%202018.pdf.

Italian Law, (1998), Law of 18 November 1998, No 415, Modifications to the Law 11 February 1994, No 109 and further dispositions as regards public works (in Italian), *Official Journal of the Republic of Italy*, No 284, 04.12.1998, Ordinary Supplement No. 199, Rome.

LD, (2003), Legislative Decree No 387/2003 of 29 December 2003, Implementation of Directive No 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, (in Italian), *Official Journal of the Republic of Italy*, No 25, 31.1.2014, Rome.

LD, (2006), Legislative Decree No 152/2006 of 3 April 2006, Code on the Environment (in Italian), Official *Journal of the Republic of Italy*, No 88, 14.04.2006, Ordinary Supplement No 96, Rome.

LD, (2010a), Legislative Decree No 75/2010 of 29 April 2010, Reform and Revision of Discipline on Fertilizers, in accordance with Article 13 of Law July 7th 2009, No 88 (in Italian), *Official Journal of the Republic of Italy*, No 126, 26.5.2010, Rome.

LD, (2010b), Legislative Decree No 205/2010 of 3 December 2010, Dispositions of implementation of the Directive 2008/98/CE of the European Parliament and of the Council of 19 November 2008 relative to waste and abrogating some directives (in Italian), *Official Journal of the Republic of Italy*, No 288, 10.12.2010, Ordinary Supplement No 269, Rome.

Mateescu C., Băran G., Băbuţanu C.A., (2008), Opportunities and barriers for Development of biogas Technologies in Romania, *Environmental Engineering and Management Journal*, **7**, 603-607.

MD, (2016), Ministerial Decree of 23 June 2016, Incentives for electricity produced from renewable energy sources other than photovoltaics (in Italian), *Official Journal of the Republic of Italy*, No 150, 29.6.2016, Rome.

Pastorek K., Kara J., Jevic P., (2004), *Biomass as Renewable Source of Energy: Economics and Energy Aspects*, FCC Public, Prague.

Ronchi E., Morabito R., (2012), *Green Economy, to Get Out of the Two Crises*, Ambiente Publisher, Milan, Italy.

Salomon K.R., Lora E.E.S., (2009), Estimate of the electric energy generating potential for different sources of biogas in Brazil, *Biomass and Bioenergy*, **33**, 1101-1107.

Scarlat N., Dallemand J-F., Fahl F., (2018), Biogas: Developments and perspectives in Europe, *Renewable Energy*, **129**, 457-472.

Vasmara C., Marchetti R., (2018), Spent coffee grounds from coffee vending machines as feedstock for biogas production, *Environmental Engineering and Management Journal*, **17**, 2401-2408.