Comparison of biogas upgrading technologies: an Italian study case

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The source sorted organic fraction of municipal solid waste (SS-OFMSW) is rich in organic biodegradable compounds, and it is suitable for biological degradation treatments such as composting and anaerobic digestion (AD). The primary product of AD is biogas, that nowadays represents an important renewable energy source (Miltner et al., 2017). The main components of biogas are methane (vol, 50-75% CH_4) and carbon dioxide (vol, 25-45% CO_2); in addition there are traces of water (vol, 2% H_2O) , hydrogen sulphide (vol, 20-20,000 ppm H_2S), nitrogen (vol, <2% N_2), oxygen (vol, <2% O_2) and hydrogen (vol, <1% H_2) (Mata-Alvarez, 2002). A well-established biogas valorisation process is the cogeneration through internal combustion engine or turbine, for the production of electric energy and thermal energy. In the field of biomass energy conversion techniques, the biogas upgrading technologies represent an alternative pathway to valorise the produced biogas. Biogas upgrading is a method to clean the biogas from carbon dioxide and the other minor compounds, in order to generate a product, called biomethane, with a high content of methane (vol, 90-99%) (Sun et al., 2015). The substitution of fossil fuels with the biomethane produced from biogas systems can increase the primary energy savings instead of converting it to green electricity only (Pöschl et al., 2010).

In this study, various biogas upgrading technologies are taken into account with the aim to evaluate the benefits which can be obtained from each technology from energy, environmental and economic points of view.

The present work is based on a real study case located in Arezzo, central Italy. Here, Aisa Impianti S.p.A. presently operates a composting plant, processing 23,000 t/year of SS-OFMSW. The amount of SS-OFMSW is constantly increasing year by year, thanks to the implementation of improved separate collection methodologies. Thus, the company is planning to build a dry AD plant, able to process 35,000 t/year, upstream the composting one. The technology based on gas-proof box-shaped reactors, operated in batch mode at mesophilic temperatures, was preliminarily selected, for its ability to treat substrates with a high content of dry substance (20-40% of total solids) (Angelonidi and Smith, 2015).

In order to process 35,000 t/year, it was assumed to feed the plant with a steady flow of about 96 t/d of SS-OFMSW. Table 1 reports the characteristics of the flow in terms of total solids (TS), total volatile solids (TVS) and water (W).

Table 1. Entering flow, and its characteristics.

	Weight [%]	[t/day]
TS	26	25
TVS*	84	21
W	74	71

*as percentage of TS

According to (Neri et al., 2018), the generated biogas volumetric composition is assumed to be 60% CH_4, 38% CO_2, 250 ppm H_2S and 2% H_2O. A precautionary specific gas production (SGP) equal to 0.345 Nm^3 of produced biogas per kg of TVS supplied to the reactor (Nagao et al., 2012) was assumed, obtaining about 75 Nm^3 of biogas per t of treated SS-OFMSW. The daily flow of dry biogas is about 7,204 Nm^3/day.

Concerning the upgrading process, the company has not yet selected the most appropriate one for the specific case. For this reason, a detailed analysis was carried out in reference to the Italian market.

There are many techniques of upgrading processes. Currently, the physical/chemical ones such as absorption, adsorption and membrane separation are the most widespread (Angelidaki et al., 2018).

Data were collected from the main companies offering biogas upgrading plants for the Italian market, in order to describe in details the operating principles, the energy and reactants consumptions, the biomethane production efficiencies and the methane losses, with particular reference to the study case. The different processes were compared considering their overall energy and environmental performances.

Additionally, data on investment and operation costs were gathered for the different options. Then considering the Italian incentive scheme for biomethane injection into the natural gas grid (GME – Gestore Mercati Energetici, 2018) and its use in the field of transportation (Ministero dello Sviluppo Economico, 2018), the costs and revenues in the different cases of application of the considered technologies were evaluated.

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