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18th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 5th-8th November, 2014, Rimini, Italy

Selected papers (2)

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Selected papers (2)

In memory of

Professor Matei Macoveanu,
founder of the school of environmental engineering and management
at the *Gheorghe Asachi* Technical University of Iasi, Romania

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Procedia Environmental Science, Engineering and Management (P - ESEM) is a journal focusing on publishing papers selected from high quality conference proceedings, with emphasis on relevant topics associated to environmental science and engineering, as well as to specific management issues in the area of environmental protection and monitoring.

P - ESEM facilitates rapid dissemination of knowledge in the interdisciplinary area of environmental science, engineering and management, so conference delegates can publish their papers in a dedicated issue. This journal will cover a wide range of related topics, such as: environmental chemistry; environmental biology; ecology geoscience; environmental physics; treatment processes of drinking water and wastewater; contaminant transport and environmental modeling; remediation technologies and biotechnologies; environmental evaluations, law and management; human health and ecological risk assessment; environmental sampling; pollution prevention; pollution control and monitoring etc.

We aim to carry important efforts based on an integrated approach in publishing papers with strong messages addressed to a broad international audience that advance our understanding of environmental principles. For readers, the journal reports generic, topical and innovative experimental and theoretical research on all environmental problems. The papers accepted for publication in *P – ESEM* are grouped on thematic areas, according to conference topics, and are required to meet certain criteria, in terms of originality and adequacy with journal subject and scope.

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ECOINNOVATION1 - Tools for evaluating the sustainability of products / processes

LIFE CYCLE ASSESSMENT OF ELECTRICITY PRODUCTION FROM ANAEROBIC DIGESTION OF ANIMAL SLURRY IN A FARM SCALE PLANT*

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Abstract

The aim of this study is to assess the environmental profile of electricity production from an AD plant fed with cattle slurry (100 kW). Using LCA method, the environmental performance of electricity production from biogas has been evaluated using 1 kWh of electricity as functional unit.
For the definition of the environmental profile, all processes involved as well as the processes avoided by the biogas production system (e.g. thermal energy production) were evaluated. The most critical stages were identified. The results show that livestock slurries are a good feedstock for AD plants from an environmental point of view.

Keywords: anaerobic digestion, biogas, environmental performance, renewable energy, sustainability

1. Introduction

During the past 20 years, agricultural biogas production considerably increased, and nowadays, more than 1,100 agricultural biogas plants are running mainly in northern Regions (Negri et al., 2014). At the end of 2012, the installed electrical power was 756 MW and 1.65% of the Italian electric consumption has been produced by agricultural biogas plants. Most of these biogas plants are located in Northern Italy.

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However, over the years, the spread of AD plants, often concentrated in specific areas (such as the provinces of Cremona, Lodi and Mantua in Lombardy), resulted in the growth of concerns about the fact that more and more agricultural land is tilled for feeding the digesters. In 2013 growing seasons, about 10% of the overall Italian maize area (approximately 10.000 km^2) (Negri et al., 2014) is earmarked to biogas production.

Therefore, the public incentives framework for electricity production from biogas has been updated with the Ministerial Decree of 6 July 2012 (MDE, 2012). In general, the incentives have been reduced (15-35%) and more importance has been paid to the heat valorization and the by-products utilization, by means of the introduction of bonus prices. From the January 1 2013, the highest incentives are granted to small plants (electrical power < 300 kW) mainly fed with by-products (minimum 70% of the biomass introduced into the digesters). As a consequence, big AD plants completely fed with energy crops aren't profitable while, on the contrary, good economic performances can be achieved through small AD plants fed with animal slurries.

Nevertheless these feedstock are though characterized by low specific biogas productions (approximately 5-25 times smaller than maize silage) (Negri et al., 2014). The feeding of the AD plant with these slurries only, allows getting the highest subsidy even though, on the other hand, it requires the construction of big digesters with consequently higher costs; in addition to this, it might turn out to be necessary the involvement of long transport distances for the feedstock.

Electricity generation by AD technology does not necessarily lead to sustainable practices (Whiting and Azapagic, 2014). The GHG savings get by the substitution of EE generation by fossil sources can be offset by the GHG emissions during the production transport and transformation of the biomass. The environmental performances of EE produced by AD plants should be carefully evaluated by means of scientific and robust methodologies. In this context the Life Cycle Assessment (LCA) allow a fair and complete evaluation of the biomass-to-electricity process. Over the years, several LCA studies have been published with regards to this topic (Bacenetti et al., 2013; Dressler et al., 2012; Lansche and Muller, 2012; Lijo et al., 2014a; Lijo et al., 2014b) but few studies are focused on EE generation in small AD plants fed only with animal slurries.

2. Objectives

The main aim of this study is to evaluate the environmental sustainability of electricity produced in a small AD plant located in Cremona District (Lombardy) and completely fed by cow slurry. Secondarily alternative scenarios able to mitigate the environmental load have been evaluated.

3. Materials

The AD Plant has electrical power of 100 kW, is located in Cremona district (Lombardy Region), it has 1 digester and is fed only with cow slurry. Animal slurry is firstly transported by a slurry tank coupled with a tractor for 0.1 km. After that it is pumped into a continuously stirred tank reactor with a global volume of 1885 m^3. Daily, 35 t of cow slurry are digested. Inside the digester, the organic matter keeps homogenous by means of a single central mixer (18.5 kW). The reactor operates at a mesophilic temperature of 42º C with an organic loading rate (OLR) of 1.6 kg VS$\cdot$ $m^{-3}\cdot day^{-1}$. The biogas produced is stored separately from the digester in a tank of 150 m^3 of capacity.

Previously to feed the CHP engine the biogas is desulphurised and dehumidified. Digestate is stored in an open-air lagoon from which both ammonia and methane are released.

These emissions are assumed at 8.9 kg/MWh for methane and 0.23 kg/MWh for ammonia (Whiting and Azapagic, 2014).

The EE needed to run the biogas plant (selfconsumption) is taken from the grid while thermal energy to heat the digester comes from the CHP engine. Globally electric self consumption reaches the 7% of gross EE produced.

Regarding the heat cogenerated by the CHP engine, part (55%) is used to heat the digester. The surplus heat is partially wasted (13%) and partially valorized in the farm for 2530 hours each year (32%). In more details, 2 h/day it is used for hot water production while, from 15 October to 15 March, it is used (12 h/day) to heat farm buildings (farmer house, offices, etc.).

4. Methods

Considering that the function of the system is electricity supply to the national grid 1 kWh of electricity produced has been chosen as Functional Unit. The system boundary includes cow slurry transport and anaerobic digestion, electricity generation and digestate storage. Cow slurry production has been excluded from the boundary because it is a waste belonging to the milk production process. The emissions from the digestate application are similar to the ones from slurry application; therefore, this process has been excluded too. The surplus heat valorized offset the production of the same thermal energy by a natural gas boiler.

The midpoint impact assessment methods recommended by ILCD Handbook were used in the study. The following impact categories have been evaluated: Climate Change (CC), Ozone Depletion (OD), Photochemical Ozone Formation (POF), Acidification (AC), Freshwater Eutrophication (FE), Marine Eutrophication (ME), Mineral, Fossil and Renewable resource Depletion (MFRD).

5. Results and discussion

Table 1 reports the environmental performance for 1 kWh of EE produced by the AD plant. For 3 out of the 8 evaluated impact categories (OD, FE and MFRD) the score is negative; therefore the EE presents an environmental benefit. This is due to the valorization of surplus heat that avoid the generation by a fossil fuel source (natural gas). Without the heat valorization, the scores for all the impact categories turn out to be numerically positive with a negative environmental load. The main hotspots of the system are: (i) the digestate storage for CC and TE due to the emissions of methane and ammonia; (ii) the CHP emission for POF, TE and AC; (iii) the anaerobic digestion for FE. The transport, thanks to the short distance, has a little impact for all the impact categories.

Table 1. Environmental performances for the FU (1 kWh)

Impact category	***Unit***	***AD***	***Digestate Storage***	***CHP emission***	***Transport***	***Heat Valorisation***	***Total score***
CC	kg CO2 eq	0.041	0.235	0.105	0.001	-0.110	0.271
OD	kg CFC-11 eq	$3.76\cdot10^{-9}$	0.00	0.00	$7.98\cdot10^{-9}$	$-1.69\cdot10^{-8}$	$-1.31\cdot10^{-8}$
POF	kg NMVOC eq	$1.07\cdot10^{-4}$	$9.49\cdot10^{-5}$	$2.93\cdot10^{-3}$	$5.63\cdot10^{-6}$	$-1.06\cdot10^{-4}$	$3.03\cdot10^{-3}$
AC	molc H+ eq	$2.36\cdot10^{-4}$	$6.95\cdot10^{-4}$	$1.54\cdot10^{-3}$	$4.93\cdot10^{-6}$	$-1.12\cdot10^{-4}$	$2.36\cdot10^{-3}$
TE	molc N eq	$3.60\cdot10^{-4}$	$3.11\cdot10^{-3}$	$8.86\cdot10^{-3}$	$1.97\cdot10^{-5}$	$-2.46\cdot10^{-4}$	$1.21\cdot10^{-2}$
FE	kg P eq	$5.19\cdot10^{-8}$	0.00	0.00	$1.81\cdot10^{-8}$	$-1.29\cdot10^{-7}$	$-5.85\cdot10^{-8}$

ME	kg N eq	$3.22 \cdot 10^{-5}$	$2.12 \cdot 10^{-5}$	$8.09 \cdot 10^{-4}$	$1.78 \cdot 10^{-6}$	$-2.24 \cdot 10^{-5}$	$8.42 \cdot 10^{-4}$
MFRD	kg Sb eq	$4.62 \cdot 10^{-8}$	0.00	0.00	$3.44 \cdot 10^{-8}$	$-1.17 \cdot 10^{-7}$	$-3.63 \cdot 10^{-8}$

Two alternative scenarios (AS) able to reduce the environmental impact of EE have been evaluated. In AS1 all the surplus heat is valorized and it substitutes thermal energy produced by the natural gas; in AS2 the digestate storage tank is covered and, therefore, methane and ammonia emissions are reduced (-80%). Fig. 1 reports the comparison among the different scenarios. The two alternative scenarios improve the environmental performance of EE. In particular, the full utilization of surplus heat causes considerable improvement for OD, FE and MFRD while to store the digestate in covered tanks reduces significantly CC (-70%) but also AC (-24%) and TE (-21%). The two AS achieve only little impact reductions for POF and ME, which are mainly due to CHP emissions.

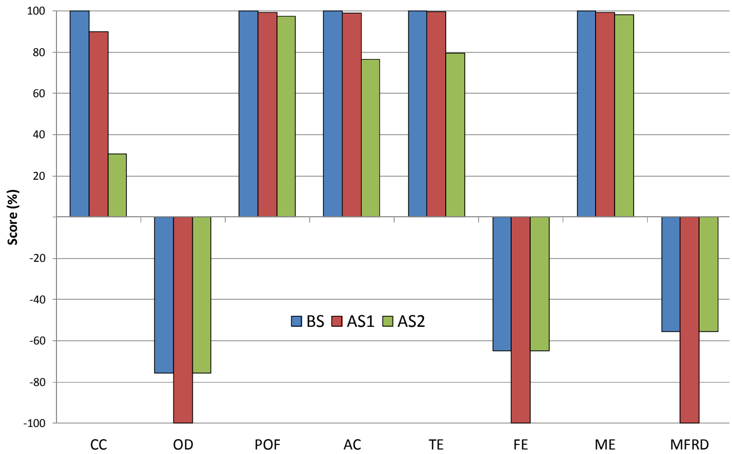

Fig. 1. Comparison among the three different alternative scenarios

6. Conclusion

The results of this study indicate that livestock slurries are a good feedstock for AD plants from an environmental point of view. Benefits for the environment are achieved avoiding heat production from fossil fuel. Furthermore, a full exploitation of thermal energy cogenerated and the covering of the digestate storage tank can lead to significant reductions in most impacts of electricity from anaerobic digestion.

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