Monitoring of a co-digestion plant in dairy cattle farm in Northern Italy

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Abstract

This paper reports results of the monitoring of a biogas co-digestion plant which treats cattle manure, energy crops and agro-industrial residues. The plant is composed of two 1200 m^3 completely stirred tanks and two 1000 m^3 storage. The biogas is burned in two cogenerators (CHP) that can supply 115 and 240 kW of electrical power. The biogas plant has been monitored since the beginning of its operation to check biogas production and yields. The average biogas yield obtained during the monitoring period was 0.74 m^3 of biogas per kg of volatile solids loaded into the digesters. The monitoring and the economic analysis clearly shows that the introduction of the plant brought significant benefits to the farm.

Keywords: Agro-industrial residues; Anaerobic digestion; Biogas yield Cattle manure; Energy crops

Introduction

EurObserv'ER estimated a biogas production of 353.8 ktons, (about 4 TWh) in Italy in 2006 of which 80% recuperated from MSW landfills. There are about 45 co-digestion plants in Italy including seven centralised co-digestion plants which treat animal manure + organic waste from the food industry +sewage sludge+ biowaste. In addition, about 65 plants exclusively process animal manure. In recent years some biogas plants have also begun to treat energy crops. Almost all the above plants are situated in North Italy. Experience of the anaerobic digestion of the MSW organic fraction, from both source collection and mechanical selection, is still limited.

The CRPA has been monitoring an anaerobic digestion plant located close to Bologna in the Emilia-Romagna region since its first months of operation in the summer of 2005.

This co-digestion plant treats cattle manure from the farm together with agricultural residues and energy crops (forage, maize silage, onions and potatoes residue, beet pulps and other seasonal biomasses).

Material and Methods

The plant is composed of two 1200 m^3 completely stirred tanks and two 1000 m^3 storage tanks which are neither insulated nor heated. One storage tank is covered by an elastomeric membrane that captures and stores biogas. The other tank is used as a storage tank for digestate before its agronomic use.

The digesters are heated by means of a steel pipe coil in which hot water from the cogeneration plant circulates, maintaining digestion temperature of about 39 °C; the side walls are insulated with polystyrene (about 8 cm thick).

Cattle manure is introduced into the first digester on a daily basis by means of a pump connected to the slurry pit. Biomass is loaded through a hopper equipped with a charging auger.

The biogas collected and stored in a plastic dome in the first storage tanks is treated by biological desulphurization system (with addition of air) to reduce the content of hydrogen sulphide.

The biogas is burned in two cogenerators (CHP) that can supply 115 and 240 kW of electrical power. Electrical energy production is partly used for farm and digestion plant requirements and the rest is sold to the national grid. About 30 to 50% of the thermal power is used for the heating of the digesters and for farm requirements including the heating of the farmhouse during the winter.

The biogas plant has been monitored since the beginning of its operation (September 2005) to check biogas production and yields. The following parameters have been monitored every fifteen days:

- cattle manure and biomass loaded to the plant;
- temperature of manure loaded to the plant, inside digesters and storage tanks;
- air temperature and humidity outside the plant;
- biogas quality;
- biogas production;
- hours of operation of cogenerators and mixers;
- electrical energy production;
- chemical characteristics of cattle manure, biomasses and slurry in digesters;
- ordinary and supplementary maintenance.

The daily supply data over the first months of monitoring were estimated from the type of biomass and numbers of loads recorded daily by the farmer. A new hopper equipped with a weighing system giving precise load values was installed in November 2006.

Data for the temperature inside digesters and in the covered storage tank and the hours of operation of the cogenerators and mixer systems are taken from electrical board placed close to the digesters. Data for the electrical energy produced and sold to the grid are recorded from the plant meter and from the national grid (Enel) web site.

Biogas quality is measured with a gas analyser (Geotechnical Instruments - GA2000 Plus) that accurately quantifies the concentrations of the main constituents, CH_4, CO_2, O_2 in percent and NH_3 and H_2S in ppm.

Digesters slurries, cattle manure and biomass are sampled during the monitoring days and analysed for pH, total solids, volatile solids, TKN, ammonia-N, phosphorus, potassium. Slurry is also analysed for COD, volatile acids and alkalinity.

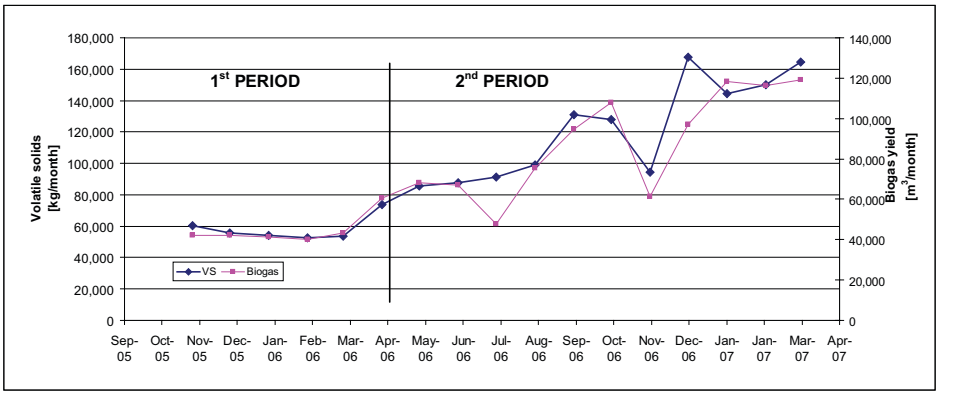
Results and Discussion

Table 1 shows the main production and operative parameters of the plant recorded over the monitoring period from November 2005 to March 2007. This period can be divided into two parts: the first from the beginning of its operation to the installation of the second cogenerator (240 kWe) in April 2006 and the second up to March 2007 when the farmer increased the biomass load.

Figure 1 shows average monthly values of organic loads and biogas production. It should be noted that plant maintenance was effectuated in June and November of the second

period in order to upgrade the mixer system and to install the new hopper resulting in a drop in biogas production at those times.

Figure . Average monthly values of biogas production and organic loads



The 110 kW cogenerator has operated for a total of 11,500 hours producing 1,057,600 kWh since the beginning of its activity in August 2005 until the end of March 2007 and the 240 kW cogenerator has operated for a total of 6500 hours producing 1,300,000 kWh from April 2006.

The average biogas yield obtained during the monitoring period was 0.74 m^3 of biogas per kg of volatile solids loaded into the digesters. This value has been calculated taking into account the electrical efficiency of the cogenerators (for 115 kWe is 32,8 % and for 240 kWe is 34,9%).

Table 1. Production and operative parameters (average daily and monthly values over the period November 2005 – March 2007) recorded during the monitoring period

Parameters	Unit	1st Period	2nd Period
Total animals	(n.)	238	
Number of dairy cattle	(n.)	110	
Cattle manure production	(t/day)	11.5	11.5
Biomass load	(t/day)	7	17
Electrical power installed	(kW)	115	355
Biogas production	(m3/month)	41776	86131
Electrical energy production	(kWh/month)	74167	154885
Methane percent	(%)	55	53
Biogas yield	m^3/kg VS	0.757	0.730

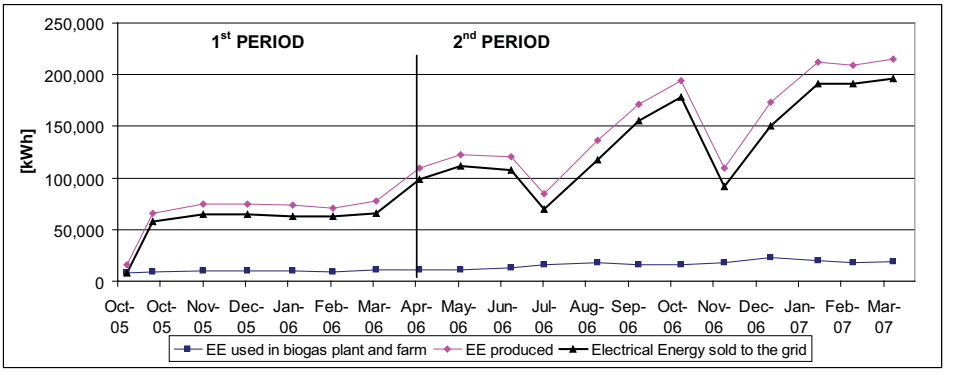
In Figure 2 we can observe that in the second period cogenerators did not operate continuously and with maximum efficiency.

The average hydrogen sulphide values obtained was 68.7 ppm over the monitoring period. In July 2006 while the covered storage tank was emptied for maintenance, values increased up to 653 ppm. From December 2006 onwards, values decreased below 10 ppm.

The temperature measured inside the digesters remained constant, an average of 39 °C for the whole monitoring period.

So far as the mixing systems were concerned, during the first period the mixer in the first digester operated on average for 4 hours/day and the mixer in the secondary digester 1.6 hours/day. With the increase in biomass load, in the second period the average daily hours of operation for the mixers were 7 and 3.6 respectively.

Figure 2. Electrical energy production, used in biogas plant and farm and sold to national grid (kWh/month)



Conclusion

Biogas yields recorded during the monitoring period were high, with an average of 0.74 m^3 per kg of volatile solids loaded into the plant. This confirms the validity of the process of anaerobic co-digestion of biomass from different origins.

During the monitoring it was also possible to draw up the economic balance sheet deriving from the introduction of the biogas plant into a dairy farm. Milk production costs and profitability were examined and then compared with the farm's situation without the presence of the biogas plant.

The analysis clearly shows that the introduction of the plant brought significant benefits to the farm. Even in the first year, when the plant had not yet entered into full production, it provided the farmer with a profit.

Aknowledgements

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