MONITORING OF AN ANAEROBIC DIGESTION PLANT IN A CATTLE FARM IN PIEDMONT

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1 INTRODUCTION

Energy production trough anaerobic digestion of agricultural residues is a promising technology in line with the objectives of Kyoto protocol (UN, 1998). To promote this technology Italian government has incentivated the electric energy production from anaerobic digestion plant (A.D.P) paying a considerable price for MWhel (up to 280 euro per MWhel). Due to this economic advantage several A.D.P have been already built in Italy. In Piedmont region (north west of Italy), 10 biogas plants are already running, 11 plants are now in a start-up phase and 25 are under project. Most of A.D.P are fed with manure, sewage and energy crops with an installed electric power between 500 and 1000 kWel.

With the aim to evaluate the performances and the operating problems of the A.D.P, DEIAFA (University of Turin), thanks to a grant of Regione Piemonte and partially inside the EU-Agrobiogas project, has started the monitoring of several of those A.D.P. In this paper results obtained from the monitoring of an ADP are reported.

2 MATERIALS AND METHODS

2.1 The biogas plant

The plant is made up of two ferroconcrete digesters (volume 6000 m^3, height 6 m, diameter 36 m) and of an uncovered 6000 m^3 digestate storage tank. Each digester has two concentrical digestion ponds; the outer pond has a volume of 4000 m^3 and it is equipped with an horizontal axis mixer and a propeller mixer, the inner pond has a volume of 2000 m^3 and it is equipped with a vertical axis mixer. The digesters are not insulated and they are heated by means of a steel pipe coil in which hot water from the CHP circulates, maintaining digestion temperature close to 41°C. The digester is fed with solid and liquid substrates; solids are automatically inserted into the digester by a "mixing vagon" every 30 minutes, liquids are collected in a 140 m^3 tank and pumped in the digestion plant. The liquid substrates are mainly composed by slurry produced by the cattle (70 cows, 30 heifers and 80 bulls) of the farm. The substrate enters in the outer part of the first digester, it overflows in the inner part of the same digester, it passes to the outer part of the second digester and to the inner part of the same digester from which it is discharged. The digested slurry is then mechanically separated. Part of the solid fraction is reused in the plant, the other part is land distributed or sold to other farms. The liquid fraction is stored in the storage tank and land applied in the period from March to November. The storage tank is equipped with a floating cover which collect the biogas produced by the stored slurry.

The biogas produced by the digesters is mixed with an appropriate amount of air to eliminate the excess of H_2S. Biogas is stored in a 500 m^3 gasometer by a stainless steel pipe line which is slightly tilted to eliminate the condensed water. Biogas is then compressed by a centrifugal pump, filtered with a paper filter, and utilized by the CHP. This device can supply 1MW of electrical power and 2MW of thermal power burning about 500 m^3 of biogas per hour.

2.2 The monitoring activity

The biogas plant was monitored over the year 2009. The monitored parameters were:

- type and amount of manure and biomasses used to feed the plant
- main chemical components (total solids, volatile solids, crude ash, pH) of each substrate and of the digestate
- digesters temperature
- hours of operation of the co-generator
- electrical energy production

- electrical energy consumed by the plant
- thermal energy production
- thermal energy consumed by the farm activity
- biogas production
- biogas components
- cost of the used biomasses.

All parameters have been monitored with a frequency of approximately 15 days.

The amount of sewage was determined measuring the flow and the running time of the pump loading the manure in the digester; the amount of feedstock was determined weighing all feedstocks.

Samples of sewage, manure, biomasses, digested slurry and of mechanical separated solid and liquid fractions were monthly collected. For each sample, the amount of total solids, volatile solids and crude ash were determined according to the AOAC official method (2000). The pH was measured with the Hanna HI 9026 pH meter.

According to substrate quantity and chemical data, organic loading rate was calculated.

The digester temperature, the hours of operation of the co-generator, the electrical energy production and electrical energy used by the plant were collected from the electronic system which control the biogas plant.

Since the electronic system doesn't record the thermal energy produced, this latter was estimated by considering the working hours of CHP and its thermodynamic efficiency.

The biogas production was indirectly estimated by considering the co-generator hourly consumption (500 m^3 of biogas per hour).

The biogas composition in terms of methane, carbon dioxide, oxygen, hydrogen and hydrogen sulphide concentration was measured by a gas analyser (Drager X-am 7000 multi gas monitor). The cost of all the used biomasses was registered by the plant owner. Considering the price of electric power produced by the biogas plant and the ADP management cost, an economic balance was carried out.

3 RESULTS AND DISCUSSION

In table 1 the biomasses used as A.D.P feedstock with their main chemical characteristics are reported. The plant owner used the biomasses more economically convenient in each period of the year, for this reason the organic loading rate of the plant was variable during the monitored period (figure 1).

TABLE 1 **The biomasses used during the monitoring period and their main chemical characteristics**

Biomasses	Total solids (%)	Volatile solids (%)	Crude ash (%)	pH
Sewage	5.40-5.60	4.00-4.20	1.50-1.30	6.50-6.70
Manure	25.71-16.92	22.03-14.33	4.95-2.58	8.70-8.74
Maize silage	27.31-17.27	23.03-15.90	4.21-1.37	4.00-4.06
Green maize silage	29.22-14.77	28.02-13.78	1.21-0.98	4.55-4.70
Poultry manure	68.91-57.35	51.13-38.68	17.79-17.43	8.40-8.60
Rice hulls	89.28-87.69	79.70-77.51	10.18-9.91	6.80-6.90
Drying maize residue	84.18-81.63	82.56-78.45	3.18-1.62	5.30-5.50
Solid fraction of digestate	26.49-21.55	20.84-17.77	5.57-3.85	8.90-9.05

The difference of used feedstock mixture could potentially generate a variable biogas production; for such a reason the farmer had to vary the amount of loading substrates. In figure 1 the monthly average gas production and the organic loading rate are reported. The annual average organic loading rate value was 1,11 Kg VS/m^3 dig/day and the average daily biogas production was 10826 m^3. Despite a quite variable organic loading rate over the year, average daily biogas yield always ranged between 9000 and 12000 m^3.

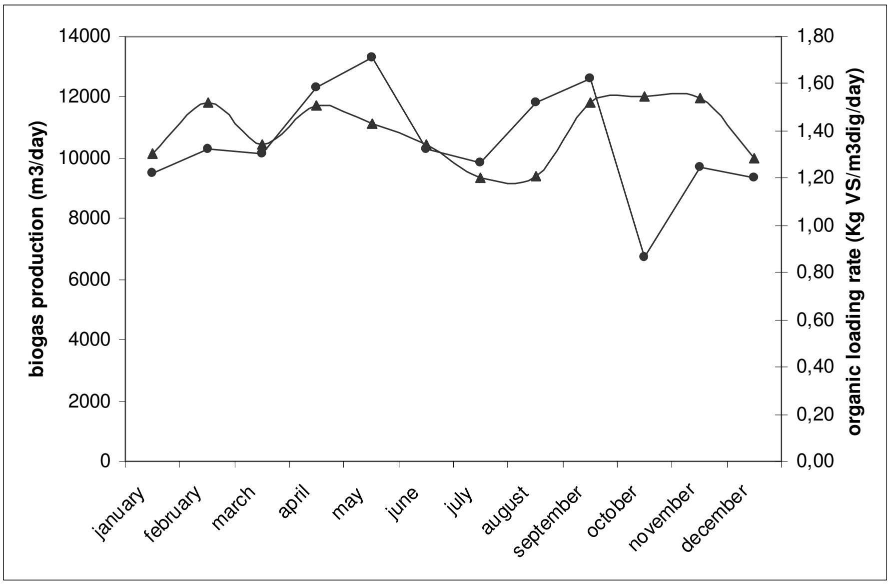

FIGURE 1 **Monthly average biogas production (▲) and organic loading rate(●)**

Daily variation of biogas yields were less accentuate than daily variation of organic loading rate. The relative stability of biogas production is due to the buffering effect generated by the high HRT of the digester (>100 days).

TABLE 2 **Average values of monitored biogas component**

Biogas component	Average value
Methane	52-56%
Carbon dioxide	39-45%
Oxygen	0,7-1,2%
Hydrogen	810-375 ppm
Hydrogen sulphide	96-346 ppm

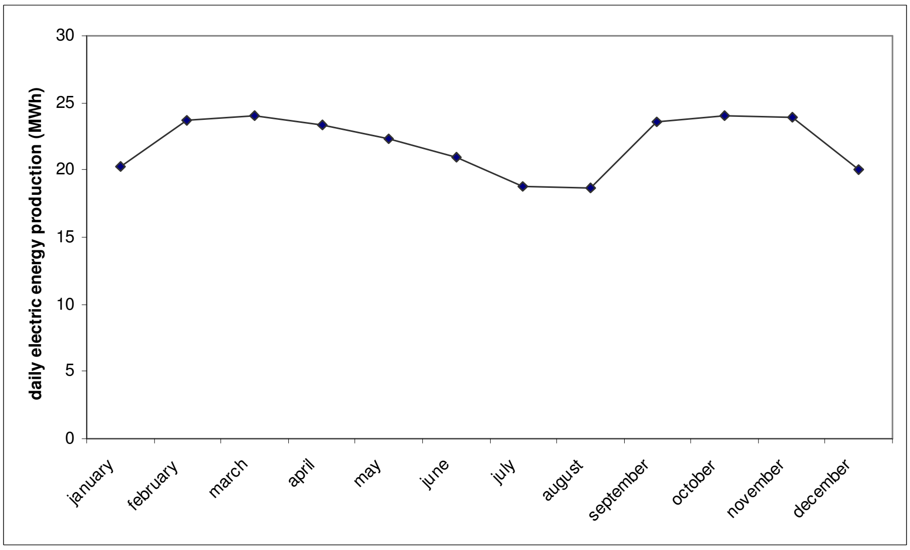

FIGURE 2 **Monthly average electric energy production**

Table 2, where are reported the concentration of the main biogas components, shows that the quality of the biogas was quite constant. The temperature value measured in both digesters were constant (41°C) during the whole monitoring period.

Figure 2 shows the variability of electric energy produced by the CHP. This latter, in detail, was 23,8 MWh. Approximately 7% of the produced electric energy was utilized for plant and farm requirement, about 250 kWh were daily used by auxiliary systems of the co-generator (biogas compressor and engine cooling system); 93% of the electric energy was sold to the national grid.

The average produced thermal energy, considering that the CHP produces about the same amount of thermal and electric energy (AB Energy package data), was of about 23 MWhel. Approximately 10% of this energy was utilized for digesters heating and for farm requirement.

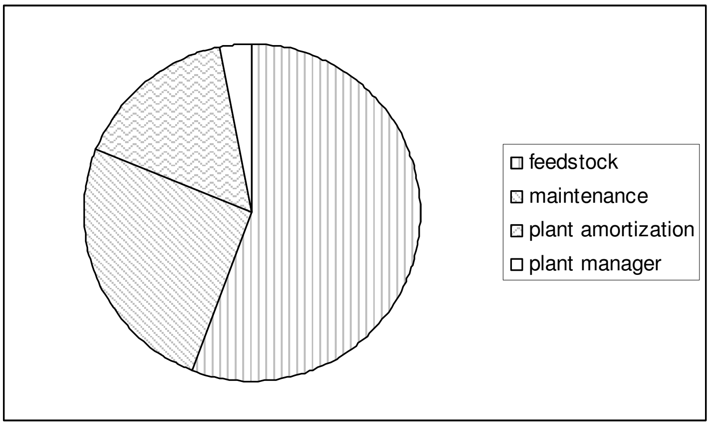

FIGURE 3 **Running cost percentage**

As shown in figure 3, cost of feedstock, including transport costs, were the main A.D.P. running cost (56%), followed by maintenance cost (25%), plant amortization (16%) and plant management cost (3%). The running costs could be reduced choosing as feedstock mainly by-product of agricultural activity produced as close as possible to the A.D.P. The total annual running cost were 1171000 Euro; this expense has been widely compensated by the electric energy sold (2262000 euro). A further gain could be obtained if also the thermal energy will be sold.

4 CONCLUSIONS

The monitoring activity showed that the use of different biomasses as anaerobic digestion plant feedstock doesn't affect the digestion process but allows the owner to utilize more economic substrate available in the different period of the year.

Despite a quite variability in the organic loading rate, the biogas production is maintained enough stable as the energy production. This allowed to have an economic benefit from the ADP.

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