STATE OF THE ART OF ANAEROBIC DIGESTION IN ITALY

S. Piccinini
Research Centre on Animal Production (CRPA). C.so Garibaldi, 42 - 42100 Reggio Emilia, Italy
s.piccinini@crpa.it

ABSTRACT

There are more than 2,000 anaerobic digesters working with animal manure in EU countries, in particular in Germany (more than 1,800), followed by Denmark, Austria, Italy and Sweden. It is estimated that biogas production in EU countries was 2762 ktep (32 million MWh) in 2002; 38% from biogas recuperated from MSW landfills. For Italy, in 2002, EurObserv'ER estimates a biogas production of 155 ktoe (about 1.8 millions of MWh). More than 1/3 of this biogas production comes from landfills of MSW. In Italy, at the end of 1999, 72 biogas plants are operating on animal slurry; five of these are centralised plants and 67 are farm plants. In Italy at the end of the eighties, a new generation of biogas systems for animal (mainly pig) slurry were developed which are extremely simplified and low-cost, involving the use of plastic cover over a slurry storage tank. These systems have been developed not only for the purpose of energy recovery but also for controlling odours and stabilizing the slurry. Though no official census has been made after 1999, information gathered from the firms that produce this type of system indicates that more than 70 of these plants have been installed in Italy up to now. The systems operate at low temperature or at a controlled temperature.

CRPA had monitored some of these biogas plants, in particular a plant installed in a large pig farm located in the province of Parma. The biogas is used for a co-generator that can supply about 50 kW of electric power and 120 kW of thermal power. The productive parameters, energetic balance and economical analysis of the biogas plant are presented in the paper: the biogas production is about 141,000 m^3/year, about 429 m^3/t lw year; the production of electric energy is about 203,000 kWh/year. In the last two years, in Italy too, the interest in the codigestion of animal slurry, energy crops and organic waste is increasing and now some codigestion plants are building and/or designing. In the paper we also present the situation in Italy of anaerobic treatment of sewage sludge, of agro-industrial waste, of organic fraction of MSW and of landfill gas utilization.

INTRODUCTION

In Europe, the spread of anaerobic digestion began in the sewage sludges stabilisation sector and there are currently an estimated 1,600 digesters operating in the area. In the present situation anaerobic digestion is considered one of the best technologies for treating industrial wastewater with a high organic load. In 1994 there were already approximately 400 industrial and centralised biogas plants in operation. There are also more than 2,000 anaerobic digesters working with animal manure in EU countries, in particular in Germany (more than 1,800), followed by Denmark, Austria, Italy, Switzerland and Sweden.

We must also consider the fact that biogas recuperation from municipal solid waste (MSW) landfills is the most important alternative energy biomass source in Europe, and Great Britain in particular, with around 450 operating plants (Observ'ER, 2003).

The use of anaerobic digestion has also increased, in recent years, with the treatment of organic waste from households (biowaste), mixed with other industrial organic waste and animal manure (co-digestion). In particular, in Denmark, there are currently 21 operative centralised co-digestion plants which annually treat around 1,000,000 tons of animal manure and 325,000 tons of industrial organic residue and biowaste.

Two recent publications (De Baere, 1999, Wellinger, 2002) recorded about 130 anaerobic digestion plants in Europe which treat more than 2,500 tons/year of organic fraction from MSW (from both source collection and mechanical selection) and/or industrial organic residues. Their is a potential annual treatment of over 5.5 million tons (with circa 1/5 coming from organic fraction of MSW and/or industrial organic residue, the rest is essentially animal manure) which can be used to produce circa 1,000 MWh per year of electrical energy. The capacity for treating solid organic fractions (excluding sewage sludge) has increased from 122,000 ton/year to circa 1.1 million ton/year in the last ten years. Most of the plants have been built in Germany (53), Denmark (21), Switzerland (11) and Sweden (10).

It is estimated that biogas production in EU countries was about 2762 ktep (32 millions MWh) in 2002, about 38% from biogas recuperated from MSW landfills (Observ'ER, 2003).

The member countries of the EU produce a total of about 1,200 millions tons of organic waste each year, of which about 90% comes from animal manure and the rest from urban and industrial organic refuse. The potential energy which could be recovered annually from organic waste used for anaerobic digestion in the 15 countries of the European Union is about 209 million MWh.

Germany at the forefront of technology

Germany is without doubt the European country which has experienced the biggest growth in anaerobic digestion over the last ten years, especially in the livestock sector. The latest data from the German Biogas Association, for the year 2003, speaks of about 2,000 existing plants with an installed electrical power of 250 MW. About 94% of the biogas plants operate in co-digestion, treating animal manure together with other organic materials, agro-industrial waste, domestic and catering waste and especially energy crops (silage maize and sorghum, forage beet, potatoes etc.) and harvest residues. The German government has introduced an important policy of incentives with prices for electrical energy produced from biogas fixed at about 0.10 €/kWh for a period of 20 years.

Italy

EurObserv'ER estimates a biogas production of 155 ktoe (about 1.8 millions of MWh) in 2002 for Italy. More than 1/3 of this biogas production comes from landfills of MSW. To encourage biogas recovery systems, in 1992 the Italian Government outlined a provision (CIP n. 6/1992) offering incentives for self-production of electric energy from biomass, paying 0.135 €/kWh in 1996 and 0.15 €/kWh in 1999 against an average cost of 0.08-0.10 €/kWh. This could translate into renewed interest in biogas systems for animal breeding. However, this rule is stopped from July 1996 and today is under revision. Italian Programme for Renewable Energy from Biomass is part of the Italian politics for reduction of greenhouse gases emissions, according to Kyoto Protocol. Now the value of Electric Energy from biogas sold to the grid is 0.12-0.13 €/kWh (green certificate=0.075-0.080 €/kWh for at least 8 years).

BIOGAS PLANTS FOR ANIMAL MANURE IN ITALY

In Italy, at the end of the Eighties, a new generation of biogas systems for animal manure (mainly pig) were developed which are extremely simplified and low-cost, involving the use of a plastic cover over a slurry storage tank. These systems have been developed not only for the purpose of energy recovery but also for controlling odours and stabilising the manure. The systems operate at low temperature or at a controlled temperature. Forty of these plants were installed up to 1999. Though no official census has been made since 1999, information gathered from the firms that produce this type of system indicates that approximately 30 more of these plants were installed in Italy between 1999 and 2002.

As of 1999, 72 biogas plants were operating on animal slurry in Italy (Piccinini, 2000). Five of these are centralised plants (*Table 1*) and 67 are farm plants. Almost all the plants are located in the northern regions (39 in Lombardia, 7 in Emilia-Romagna, 12 in Trentino-Alto Adige). The majority of the plants operate with pig slurry; cattle slurry is treated by only twelve farm plants, all in the province of Bolzano, and two centralised plants. There are still only a few plants that treat mixtures of different kinds of wastes besides those from livestock: the centralised plants also treat sewage sludge, agro-industrial wastewaters, in particular wastewaters from the olive oil processing industry, and biowaste. The majority of the farm plants in the province of Bolzano treat biowaste along with cow slurry; in winter 2003, in the province of Bolzano 25 biogas plants were operating and 6 biogas plant were buiding.

Table 1 *- Characteristics of five centralised biogas plants operating on animal slurry in Italy*

Plant	Reactor	Working temp. (°C)	Loading ($m^3 \bullet d^{-1}$)	HRT (days)	Volume (m^3)	Feedstock	Biogas use
Marsciano (Perugia)	CSTR (*)	30 – 40	800	18	14200	Pig Slurry + Agro-Industrial waste	CHP
Bettona (Perugia)	CSTR (*)	30 – 40	700	13,5	9500	Pig and Cattle Slurry + Agro-Industrial waste	CHP
Spilamberto (Modena)	CSTR (*)	30 – 40	600	20	12000	Pig and Cattle Slurry + sewage slurry	CHP
Visano (Brescia)	CSTR	30 – 40	570	21	12000	Pig and Cattle Slurry	CHP
Lozzo Atestino (Padova)	CSTR	30 – 40	500	10	5000	Agro-Industrial sludge + organic presorting fraction of MSW + Cattle Slurry	CHP

(*): double stage (second stage unmixed and unheated); CSTR: Completely Stirred Tank Reactors
CHP: Combined Heat and Power engines

The five centralised plants are all completely mixed reactors operating at an interval of mesophilic temperature (30-40°C). The farm plants are predominantly simplified and low-cost, created by installing a plastic covering over a slurry storage tank or lagoon**.** The prevalent use of the biogas is in cogeneration (combined production of heat and electric energy): cogenerators are installed in all the centralised plants and forty of the farm plants; in 21 plants, generally adjacent to cheese dairies producing Grana Padano or Parmigiano-Reggiano, the biogas is burned directly in the boiler. In the last two years, in Italy too, the interest in the codigestion of animal slurry, energy crops and organic waste is increasing and now, some codigestion plants are building and/or designing

Example of a farm biogas plant

The “S & B” pig farm, located in the province of Parma in the Emilia-Romagna Region, is a large facility that offers a classic example of the organisation of heavy swine production. The farm also incorporates a feed production plant. The farm sheds have a capacity for 330 sows and

3205 growing and fattening pigs. The average live weight amounts to about 330 tons.

The biogas system (*Figure 1*) was created by adapting the tanks used for slurry storage. The slurry reaches a shaft from which a pump lifts it and sends it to a rotating screen for separating the coarse solid fraction. The separated solids are collected in the underlying concrete platform.

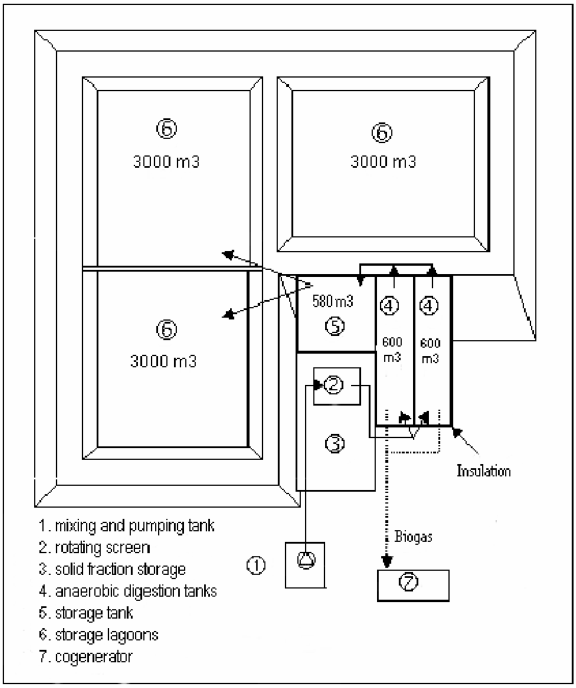

Figure 1 *- "S & B" farm: plan and flow-sheet of the biogas plant*

The liquid part is divided into two identical flows by a hydraulic separator, and then conveyed to two parallel digester tanks of the same size. Each digestion line is thus independent, and is composed of a tank built on-site with dimensions of 25 x 6 m in plan, an average depth of 4.5 m, and total useful volume of about 600 m^3. The side walls of the digestion tank are insulated, partly with polyurethane foam (about 5 cm thick) and partly by earth embankments.

One tank was covered using a pneumatic gas-collection dome (a semi-cylindrical dome composed of three membranes in fabric with polyester fibres in the weft coated with PVC). The innermost membrane collects the biogas. The maximum gasometric capacity of this dome is about 325 m^3. The covering of the second tank was made using a semi-cylindrical dome composed of only one membrane.

The biogas is maintained at a pressure of 0.02 bar by a special valve in connection with the biogas chamber located in the first dome. This valve permits the passage of the biogas from the second dome to the first when the pressure in the second dome approaches more than 0.02 bar, while preventing the withdrawal of gas from the first dome from emptying the second. In this way, the second dome is always full of gas at 0.02 bar pressure. The geometric volume of the second dome is approximately 225 m^3. Both digestion tanks are heated by means of a steel pipe coil installed near the bottom, in which hot water from the cogeneration plant circulates.

The biogas is sent to a building in which a cogenerator is installed that can supply about 50 kW of electric power and 120 kW of thermal power. The cogenerator is equipped with a parallel mains board which enables it to work in parallel with other potential cogenerators as well as with the grid.

Table 2*: Influent flow-rate, biogas yield, digestion temperature of the plant (average monthly values) in the period October 1994 - June 2001.*

	Mean	**St.dev**	**Range**
Influent flow rate			
• slurry [$m^3 \cdot d^{-1}$]	64	13	36.9-91
• whey [(a)] [$m^3 \cdot d^{-1}$]	2.0	1.3	0-6.4
Digestion temperature [°C]	25.0	4.9	17.5-33.3
Biogas production [(b)]			
• per day [$m^3 \cdot d^{-1}$]	396	109	127-597
• per unit of covered area [$m^3 \cdot m^{-2} \cdot d^{-1}$]	1.322	0.364	0.423-1.990
• per unit of digester volume [$m^3 \cdot m^{-3} \cdot d^{-1}$]	0.331	0.091	0.106-0.498
• per unit of live weight [$m^3 \cdot t\ lw^{-1} \cdot d^{-1}$]	1.201	0.331	0.385-1.809

(a): input of whey began in February 1995 and was not constant

(b): biogas production was determined on the base of working hours of cogenerator; cogenerator stopped for maintenance 1 week in March 95, 7 weeks in the period September-November 1996, 6 weeks in the period May-June 1998, 10 days in December 1998, 1 week in February 1999 and for 20 days in June 1999.

Table 3*: Production parameters, energy balance and economic analysis of the biogas plant (average yearly values) in the period October 1994 - June 2001.*

Productive parameters		
• sows	(number)	330
• live weight	(t)	330
• slurry production	($m^3 \cdot year^{-1}$)	23,360
• biogas production	($m^3 \cdot year^{-1}$)	141,472
• biogas yield	(m^3 biogas$\cdot$t $lw^{-1} \cdot year^{-1}$)	429
Energy balance		
• cogenerator [(1)]	(kW)	50
• Electric Energy production	($kWh \cdot year^{-1}$)	203,178
Economic analysis		
• Sale of EE [(2)]	($€ \cdot year^{-1}$)	37598
• maintenance cost cogenerator [(3)]	($€ \cdot year^{-1}$)	6301
• maintenance cost digester	($€ \cdot year^{-1}$)	2066
• net margin	($€ \cdot year^{-1}$)	29231
• investment [(4)] (1993)	(€)	90900
• pay back time	(years)	3.1

(1) Electric power

(2) ENEL buys electric energy at 0.13 €okWh-1 in 1994-95, at 0.14 €okWh-1 in 1996, at 0.15 €okWh-1 in 1997-99 and 0.17 €okWh-1 in 2000-01.

(3) We consider 0.031 EUROokWh-1; at June 2001 cogenerator worked 33,306 hours.

(4) The cost includes: the two covers for biogas recovery (300 m2), the gasometric dome for biogas storage, the heat exchanger, the cogenerator, the housing for the cogenerator and the installation of all the above.

The system began operation in the spring of 1993. Since the first months of operation, the system has been monitored to verify the biogas yield. *Table 2* shows the main operative parameters of the plant found in the period from October 1994 to June 2001.

Table 3 summarises the production parameters, the energy balance and the economic analysis resulting from the period October 1994-June 2001. All the electric energy production was bought by ENEL (Italian national electrical agency) under a provision of the Italian government (CIP n.6/1992) that offered incentives for self-production of electric energy from biomasses.

ANAEROBIC TREATMENT OF OTHER BIOMASSES

Like in the rest of Europe, in Italy anaerobic digestors are widely used in the stabilisation of sewage sludge from municipal waste water treatment plants. A survey carried out (Gerli, Merzagora, 2000) identified approximately 120 anaerobic digestors operating in the same number of municipal waste water treatment plants, with a potential for wastewater treatment of about 21.5 million equivalent inhabitants.

Various biogas systems have also been created in the agro-industrial sector, particularly at distilleries, sugar refining plants, and factories for the production of fruit juice and confectionery products.

As regards anaerobic digestion of the organic fraction of MSW, coming from both source collection and mechanical selection, the experiences are limited:

- As regards the treatment of the organic fraction from mechanical selection, one plant is starting in Verona (4 digestors of 2000 m^3 each, capable of treating 200 t/day of organic fraction of MSW and 40 t/day of sewage sludge); one plant is starting in Villacidro (Cagliari) (2 digestors of 2000 m^3 each, capable of treating 120 t/day of organic fraction of MSW); one plant is starting in Roma, capable of treating 40,000 t/y of MSW and one plant is in the final phases of set up in Bassano del Grappa (Vicenza) (3 digestors of 2500 m^3 each, capable of treating 44,200 t/y of MSW, 8,200 t/y of biowaste, 3,000 t/y of sewage sludge).
- As regards treatment of the pre-selected organic fraction from source collection, in addition to the plant Agrilux (Padova) that work prevalently on animal manure and also co-digest biowaste (*Table 1*), one plant is starting in Pinerolo (Torino) and a plant in Camposampiero (Padova) is in the beginning phase of set up. This last plant represents a clear example of an integrated system. The plants comprising the centre (municipal waste water aerobic treatment plant, anaerobic co-digestion, cogeneration, and composting) are closely interconnected, with the aim of taking the best advantage of management and process synergies. Globally the centre will be able to treat:

  - civil and industrial wastes for a purification capacity of 70,000 e.i.;
  - up to 16,000 t/year of biowaste and green waste;
  - up to 50,000 t/year of animal manure;
  - up to 25,000 t/year of sewage sludge.

BIOGAS FROM LANDFILLS

An incentive for the construction of plants producing electric energy with the biogas taken from landfills has been given by the Cip 6/92 provision, based on which plants for approximately 100 MW have been authorised. Data from 1999 from GRTN (Management of the National Transmission Network) identify 89 plants of this type operating at Italian landfills, for a total of about 128 MW of installed power and electric energy production of about 566 GWh/y.

The total theoretical potential of all the Italian landfills would reach 1000 MW. Actually only a fraction of this figure, about 30%, can be used for energy production purposes. As a large part of this potential is concentrated in medium and large landfills, an objective of a further 200-300 MW as of 2008-2012 seems to be feasible (source: White Book on renewable energy sources by ENEA).

CONCLUSIONS

Over the last ten years, anaerobic digestion has become widely used in many European countries, including Italy. These plants are developed not only for the recovery of renewable energy, i.e. biogas, but also to control malodorous emissions and to stabilise the biomasses prior to their agronomic use. In Italy, the regulations currently being defined regarding incentives for self-production of electric energy from renewable sources (green certificate) could translate into renewed interested in biogas plants.

The process of evolution in environmental policy, also regarding the sector of energy valorisation of biomasses, activated following the Kyoto Conference on the reduction of atmospheric pollution from greenhouse gases (methane being one of the principal ones) and the recent Animal By-products EC Regulation n. 1774/2002, that suggests the anaerobic digestion for the treatment of animal by-products, could raise attention to the recovery of biogas in Italy too.

It would therefore be useful to strengthen and rationalise the systems that exploit processes of anaerobic digestion of different types of biomasses (animal manure, sewage sludge, source separated household waste, industrial organic waste, animal by-products, energy crops and crop residues), as, for example, is beginning to happen in the centralised plants described in Table 1.

We feel that the agricultural world could be interested in the opportunities provided by the concurrence of problems such as the greenhouse effect, the valorisation of organic wastes, and the need for a greater contribution of renewable energy.

The farming communities represent the main sector and the driving force for introducing biogas systems on a broad platform. The incentives are various: increasing the sustainability of the farm, new income source from green electricity, reduction of the environmental problems of emissions and odours from manure, better utilisation of nutrients in animal manure.

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