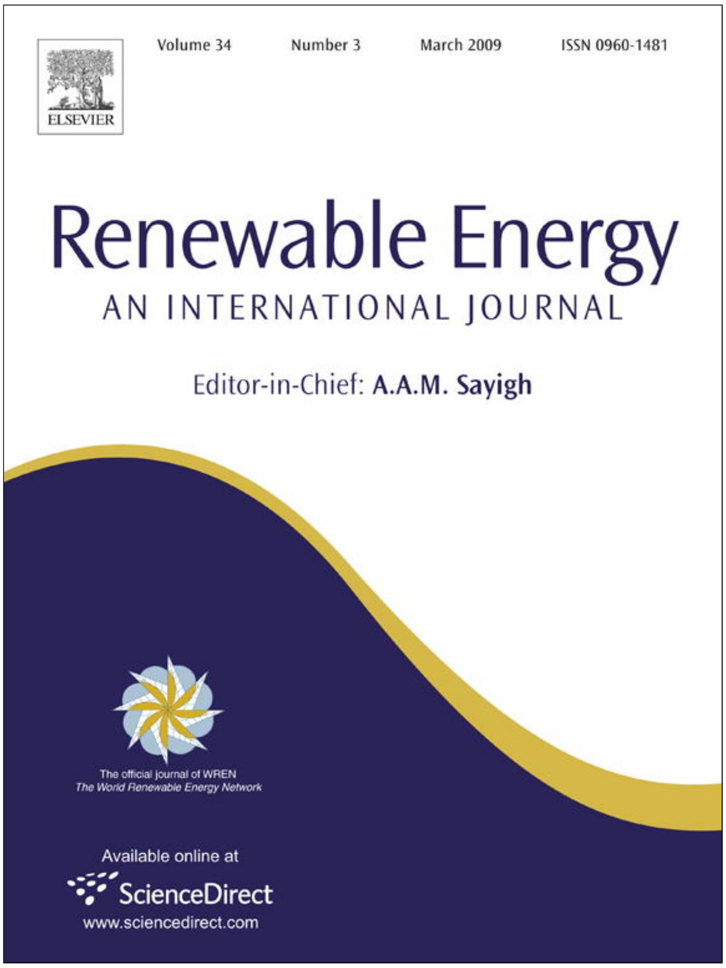

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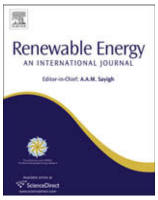

Review

State of the art and prospects of Italian biogas production from animal sewage: Technical-economic considerations

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ABSTRACT

In the last few years, the recent regulations of the Energy and Environment Policy of the European Union (EU) Energy Policy, together with the new Common Agricultural Policy (CAP) have been aiming to increase the integration of renewable resources, and in particular of biogas, into the EU energy system thanks to the adoption of new tools for their promotion. The production of biogas from animal waste, both on a European and national level, still represents only a small percentage of the total amount deriving from anaerobic digestion of organic matter. In this context, it was deemed opportune to evaluate the state of the art in the use of biogas in Italy and its production potential, with regard to animal sewage, in the light of the current technical-economic and legislative obstacles.

1. Introduction

Within a Communitarian context, biogas represents the most widespread fuel obtained from biomass in recent years, thanks to the specific legislative tools aimed at increasing production in the various economic sectors involved: ranging from zootechnical to agro-industrial. In particular, biogas deriving from animal waste constitutes an ever increasing commodity in some EU Member States (such as, Germany, Denmark, Sweden and Austria) and also great potential in other states (such as Italy). Greater use of animal sewage, as raw material in the production of biogas, was strongly encouraged by the new guidelines for energy-environmental and agricultural policies set out in the various norms issued to this regard (such as Regulation 1774/2002 concerning disposal procedures and use of animal origin by-products [1] as well as the subsequent temporary and implementation norms, such as Regulation 810/203 EC [2], 92/2005/EC [3], 208/2006/EC [4], 209/2006/EC [5], 185/2007/EC [6], Directive 91/676/EEC regarding the spreading of nitrates [7], Directive 96/92/EC [8] and Directive 2001/77/EC [9] concerning promotion of renewable energy sources in the electricity market). The final objectives to be achieved are various: a decrease in air and soil pollution linked to their disposal; the production of an excellent amendment as a debris by-product (for fertigation or as a colloidal humus); and an increase in the amount of energy deriving from renewable sources, using simple technology already present on site.

Regarding this, Italy took its first steps at the beginning of the 1980s when realisation of biogas production plants from animal waste was essentially aimed at reducing environmental impact in the agricultural sector and not at providing clean energy. As illustrated above, nowadays the situation has changed: as well as the aforementioned necessity, though remaining of fundamental importance, there is now the need to increase the use of renewable energy sources, as alternative resources to fossils, by now in gradual depletion and heavily polluting. The new political perspectives and the recent opportunities offered by European legislation, and consequently national legislation, impose an evaluation of the potential the Italian zootechnical sector can offer in light of the current situation which does not appear satisfactory. Given the above, the aim of the present study is to analyse the current situation and the prospects of Italian biogas production from animal waste, partially estimated an another publication of the authors [10], while considering the current technical-economic and legislative obstacles which limit its spread and could affect its positive development.

2. European and Italian production of biogas: state of the art

2.1. The EU-15

Over the last decade, based on available data pertinent to the EU-15, there has been an increase of 30% in the use of renewable energy sources, increasing from approximately 300 TWh produced in 1995 to more than 400 TWh in 2005, meeting 15% of the total demand of electric energy (2700 TWh). As known, the major

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contribution to this comes above all from hydroelectric and wind energy being approximately 83% and, for the remaining part, geothermic, photovoltaic and biomass energy [11].

In the EU-15, biogas is the most widespread fuel obtained from biomass and may derive from the natural process methanization supply of organic waste present in landfills or from anaerobic digestion of sludge, crops and agro-industrial by-products and animal waste. In 2005, its primary production was more than $205\,800 \times 10^9$ kJ, with an annual increase of almost $25\,200 \times 10^9$ kJ, over the last 5 years. This quantity is derived essentially from biogas produced by landfills (64%), the degradation of urban and industrial waste (18.8%), and co-digestion of zootechnical effluents, agricultural waste and energy crops (17.2%) [12]. Great Britain and Germany are the main producing countries contributing, respectively, 39% and 35% to the entire amount (Fig. 1).

According to estimates reported in literature [12,13], based on the method considering the total amount of urban and industrial waste treated in each Member State of the EU-15, the biodegradable part of urban waste produced each year and the zootechnical sector, the theoretical potential of biogas production in 2020 should be approximately $756\,000 \times 10^9$ kJ. The previsions for 2020, relative to the single Member State, indicate France, together with the aforementioned Germany and Great Britain, as those countries which will have the highest production potential in the future (Fig. 2) (elaboration of data from Ref. [12]).

Once produced, biogas may be burnt in traditional boilers to produce heat or be utilized as fuel for generation of electric power or combined heat and power (CHP/cogeneration) by using different types of technology, mature and not, such as internal combustion engines, gas turbines, and finally the innovative fuel cells or micro-turbines. Biogas can be used to produce chemical compounds, as fuel in the automotive sector or be injected into the gas grid, these last two applications arousing ever more interest.

Its diverse uses depend on its different commodity quality, deriving from the type of chemical refining it undergoes, on various levels, to eliminate contaminants [such as, nitrogen (N_2) and oxygen (O_2), hydrogen sulphide (H_2S), carbon dioxide (CO_2) or water (H_2O)]. Naturally, these treatments affect production costs and consequently also the final price of the electricity generated. For example, if the purification process is not driven, and so it is simpler and less expensive, the final designated use of the biogas produced is for heat production, using boilers, present on the same site. If the treatment process is middling, the most convenient use is that of generating heat and electricity by means of CHP systems or gas turbines. On the contrary, if all the contaminants are eliminated from biogas, i.e. pure methane (CH_4) is obtained, it may be used as fuel for vehicles, to generate electricity and heat with fuel cells, for the production of chemical compounds or simply to be injected into the gas grid, and therefore mixed with natural gas of fossil origin (Fig. 3, elaboration of data from Refs. [14,15]).

Apart from the various possible uses, nowadays biogas is mainly used to generate electricity (2/3 of the total amount, half of which obtained using cogeneration plants) and for the production of heat (the remaining 1/3). The annual production growth rate has been rather high in the last decade, that is 24% in 2002, 13% in 2003, 22% in 2004 and 15% in 2005 [16]. The total value registered in 2005 was approximately 14 000 GWh, that is, only 0.5% of total consumption of electricity in the EU (2700 TWh), reconfirming the leading position of Great Britain and Germany (Fig. 4, elaboration of data from Ref. [12]).

Besides the production of electricity, it is interesting to consider some data relative to the use of biogas as fuel for vehicles. As already mentioned, though still limited, this use is arousing growing interest among countries thanks to its vast potential and environmental spin-offs (absence of carbon monoxide and nitrogen emissions).

At the end of 2005, only 1600 biogas filling stations existed on European territory; however, as of the end of 2006, 1000 should be operative in Germany, 100 in Switzerland and more than 50 in Austria [15]. However, the leading nation in this field is Sweden with 779 buses and more than 4500 cars fuelled by biogas [16]. The reasons for this success are due to the political tools adopted in order to spread the use of this biofuel (tax exemptions, government investment programmes, free parking for cars fuelled by biogas, etc.) and the low cost of electric energy, which has allowed the government to dedicate itself in promoting the use of biogas as vehicle fuel. Thus, the current market price is 20–30% less than petrol on energy basis: however, if the costs of innovation and production, necessary to create particular types of cars, are considered, then the final price will not be so cheap, above all for private passenger vehicles. In fact, for these the final cost of biogas will be more than 10% compared to petrol, a cost which would be absorbed only if an annual amount of more than 15 000 km is covered [17].

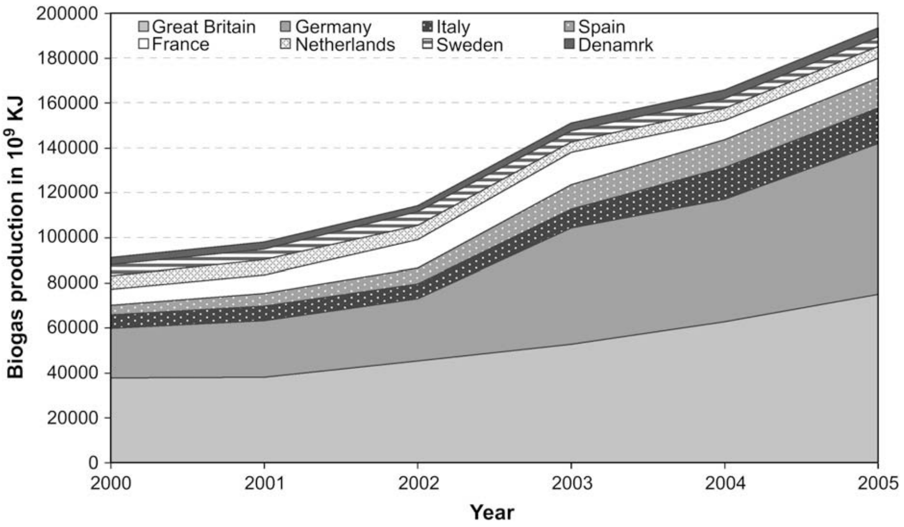

Fig. 1. Main European producing countries (2000–2005).

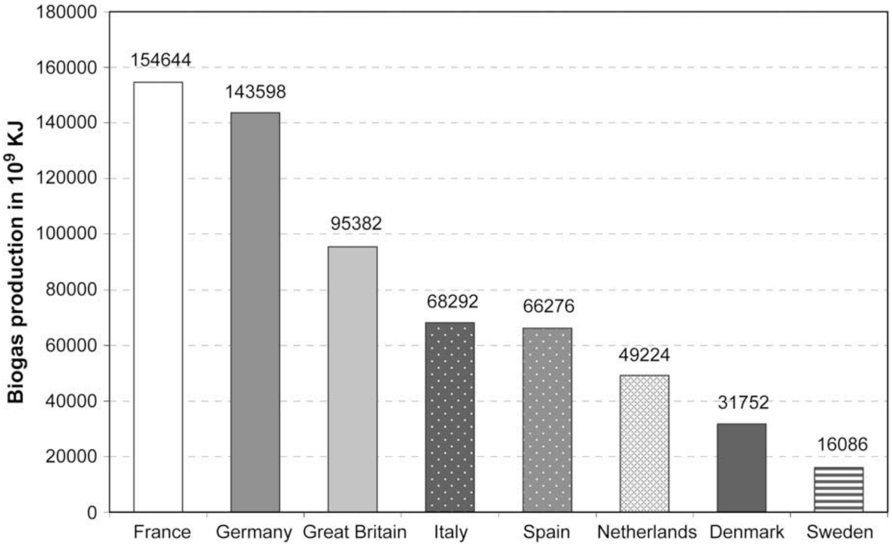

Fig. 2. Potential of biogas in 2020, for the main currently producing countries.

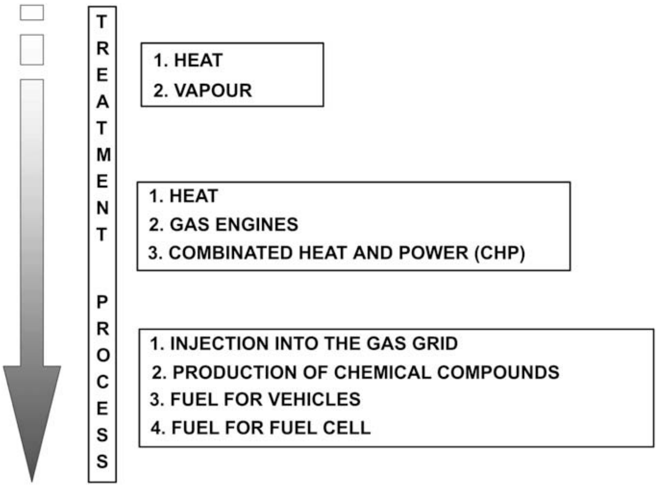

Fig. 3. Use of biogas based on the treatment process undergone.

2.2. Italy

The situation in Italy fundamentally mirrors that of the EU, with biogas being mainly used to produce electricity and heat.

In particular, the amount of electric energy in 2005 was almost 1200 GWh, that is, 2.4% of the total supplied by renewable energy sources (50 000 GWh that is 16.4% of total electric energy demand). Although the supply of biogas is low today (19.5% of electricity produced from biomass), over the last decade it has been increasing, with a total growth of approximately 100%. Most of it is obtained from organic waste present in landfills, for which, thanks to norms in force (Legislative Decree No 36 of 2003 [18] assimilated with Directive 99/31/CE [19]), there is the obligation to capture the gas emitted; a discreet quantity is also obtained from anaerobic digestion of crops and agro-industrial waste, of which a significant increase of more than 2000% as of 2001 has occurred. The remaining raw materials are represented by sludge and animal waste: generation of biogas from these substances has been, respectively, 3 and 26 GWh (Table 1 and Fig. 5; elaboration of data from Ref. [20]).

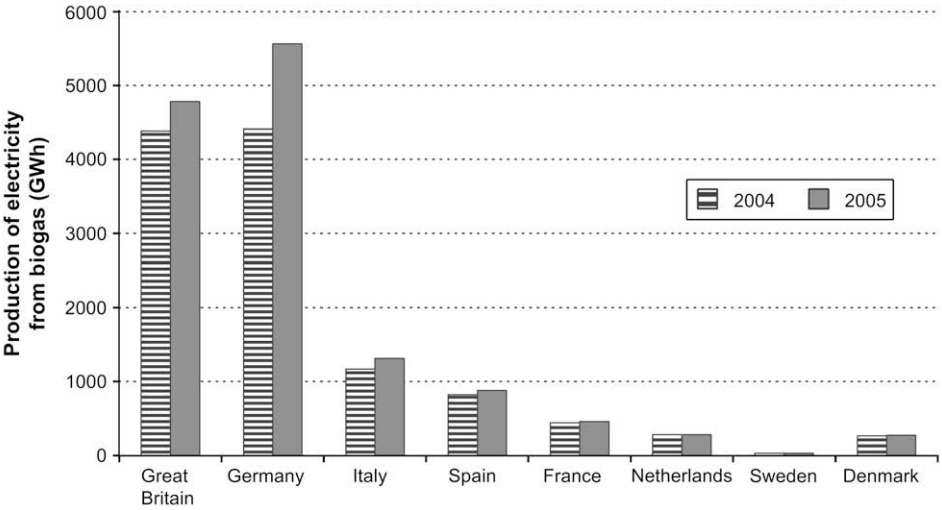

Fig. 4. Main European countries producing electricity from biogas (2004–2005).

Table 1
Italian production of biogas per source over the last 5 years

Type of material	Biogas production in GWh				
	2001	2002	2003	2004	2005
Sludge	5	3	3	1	3
Animal waste	10	16	13	19	26
Landfills	665	822	910	1038	1053
Energy crops and agro-industrial waste	5	102	102	110	110

Fig. 6 shows the trend of biogas produced only from zootechnical waste as of 1991: this has been positive, with an annual increase of 1.36 GWh, and used mainly in cogeneration plants (65%), in place of natural gas of fossil origin (Fig. 7) (elaboration of data from Ref. [20]). This occurred both due to the spread of simpler anaerobic digestion technologies, compared to those of the 1980s (created essentially to reduce environmental impact of sewage and not to produce energy) [21] and also due to the issue of laws in support of renewable sources (Provision CIP6/92 [22] and later norms such as Legislative Decree No 387 of 2003 [23]).

3. Production prospects in Italy

3.1. Materials and methods

The Decree of 7 April 2006 [24] regulates art. 38 of the Legislative Decree No 152 of 11 May 1999 [25] concerning the norms relative to the agronomic use of livestock effluents. These are defined as those which can be collected using a shovel and those not: the first ones are essentially manure (bedding waste) and the second ones are sewage (waste without bedding). While manure, being of good agronomic quality, is mainly used as fertilizer, sewage having greater nutritional quality and produced in greater quantity, by virtue of its liquid form, often does not represent a resource but rather a waste which is difficult to dispose of, thus creating serious environmental problems above all on agricultural land defined "areas vulnerable to nitrates of agricultural origin", that is, those land areas where more than 170 kg/ha of nitrogen cannot be used (Legislative Decree No 152 of 2006 [26]). As known, regional, provincial and municipal laws determine the quantity to be spread and those areas, vulnerable or not, on which to do so. For these reasons all farmers who spread sewage on lands designated for agricultural use are not only obliged to have authorization but must also carry out the correct agronomic spreading procedure, in order to avoid contaminating soil and groundwater.

To avoid such dangers the solution would be, besides those foreseen in the various regional norms (containment tanks, spreading times, distance from residential areas, amounts, periods, etc.), to use this effluent as a raw material to produce biogas, as foreseen in Annex VI of the EEC Regulation 1774/2002 [1], modified by EEC Regulation 208/2006 and 209/2006 [4,5], concerning both the specific requirements of animal by-products to be transformed and the relative biogas plants. In this last case, a series of advantages would be reached: a decrease in problems connected to disposal and, therefore, the risk of polluting soil and air, the production of an excellent soil conditioner as a resultant by-product (for fertigation or as colloidal humus) and an increase in the quantity of energy deriving from renewable sources, using simple technologies present on the same farm.

In light of this, it was decided to calculate the Italian potentiality of biogas from sewage, deriving from intensive breeding (cattle, swine and poultry) on national territory, included in the census of ISTAT (The National Institute for Statistics) of December 2004, Table 2 [27]. The effluents of sheep and goats will not be taken into account in that, although of substantial quantity, they present no difficulty in disposal, since being already partially distributed on soil thanks to the extensive or semi-extensive types of breeding.

First of all, the total amount of sewage produced in Italy was determined adopting the formula in the "Model of Zootechnical Sewage Communication" [28], illustrated below:

$$\begin{aligned}\text{Sewage volume}\left(\text{m}^3/\text{year}\right) = {} & \text{sewage produced}\left(\text{m}^3/\text{month} \times \text{ton in live weight}\right)\\ & \times \text{consistency of breeding farm}(\text{ton in live weight})\\ & \times \text{number months permanency in breeding farm}(\text{month})\end{aligned}$$

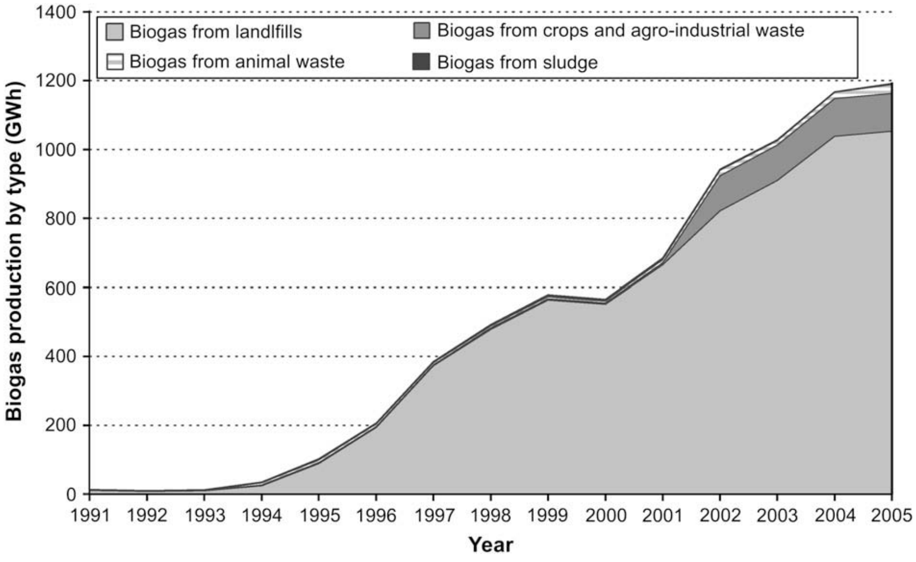

Fig. 5. Italian production of biogas (1991–2005).

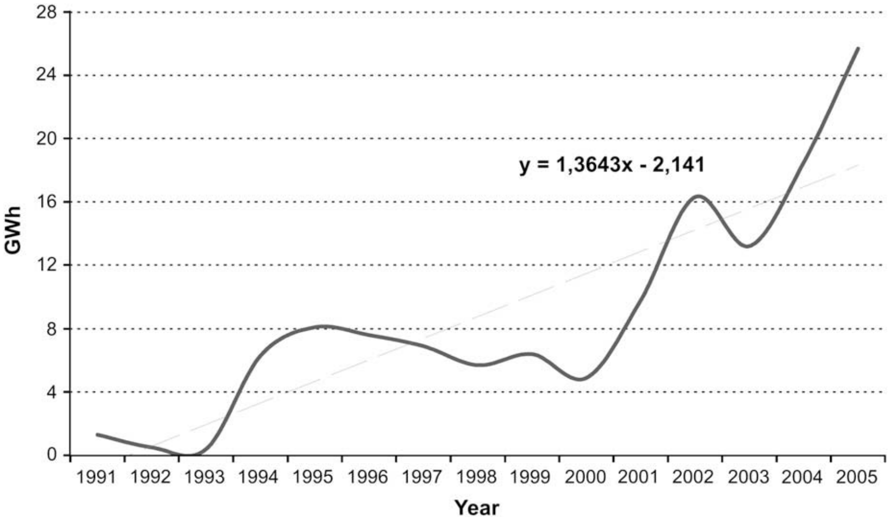

Fig. 6. Italian production of biogas deriving from animal waste (1991–2005).

The sewage produced is obtained from the values contained in the tables of the aforementioned Model of Zootechnical Sewage Communication; while the consistency of breeding farm, from the result between the total number of animals existing in Italy, defined by category, and average weight contained in the table of Legislative Decree of 7 April 2006[24]; the last is considered as 12. Consequently, an average quantity of sewage per animal species was obtained. After having calculated this value, biogas potential was evaluated, considering the average yields obtained from the anaerobic digestion process of organic matter (OM), contained in the effluents, expressed as % of dry matter (DM). These data differ based on the diverse animal species considered [29,30] (Table 3).

The total quantity of biogas produced on average from 1 ton of sewage was determined, and for the sake of convention 1 m^3, thus obtaining a conversion index (Table 4).

Therefore, the whole biogas value was determined

$$\text{Biogas}\left(\text{m}^3/\text{year}\right) = \text{sewage volume}\left(\text{m}^3/\text{year}\right) \times \text{conversion index}$$

Obviously, also calculating differently, that is, directly considering the whole content of organic matter present in the volume of sewage, the biogas yield remains the same: in fact, this is the only component to undergo the process of biochemical alteration. Once transformed, the residual part constitutes, together with other mineral nutrients, the digested sewage to be used as soil conditioner.

As previously stated, at this stage, the biogas obtained may be used to produce heat and/or electricity by means of a cogeneration system. This allows for a recovery of heat produced during combustion by means of an appropriate heat exchanger: part of the heat recovered is used to heat the digester and the rest is conveyed for thermal use. Thus, cogeneration permits utilization of up to 90% of the energy content of the fuel, 30% in electricity and 60% in heat.

For this reason, conversion in the two energy forms will be given by the equivalence, therefore, 1 m^3 of biogas produces 1.9 kWh of electricity and 3.8 kWh of heat considering the low heating value of biogas is 23 MJ/kg.

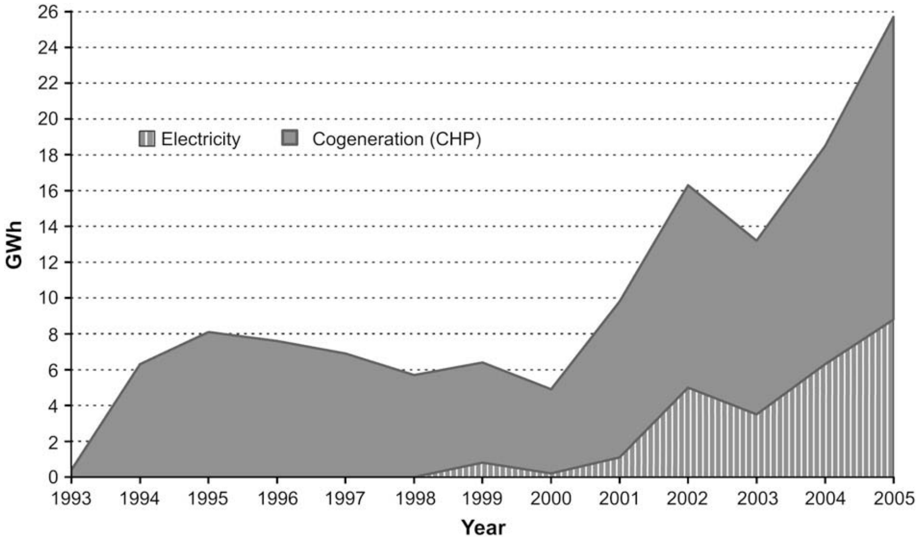

Fig. 7. Italian production of biogas from animal waste based on designated use.

Table 2
Head of livestock in Italy at 1st December 2004

Type of livestock	Number
Cattle	6 304 601
Swine	8 971 783
Poultry	172 978 729

$$\text{Electricity}(\text{kWh/year}) = \text{biogas}\left(\text{m}^3/\text{year}\right) \times 1.9\left(\text{kWh/m}^3\right)$$

$$\text{Heat}(\text{kWh/year}) = \text{biogas}\left(\text{m}^3/\text{year}\right) \times 3.8\left(\text{kWh/m}^3\right)$$

3.2. Results and discussions

The total amount of sewage produced by cattle was more than 68 million of m^3/year, mainly deriving from adult animals (dairy cattle); almost 38 million of m^3/year by swine and almost 7 million of m^3/year by poultry. Based on the previously determined conversion indexes, producible biogas from cattle is equal to 1.0 Gm^3/year, 0.6 Gm^3/year from swine and to 0.3 Gm^3/year from poultry. This data was then converted into electricity and/or heat, generable in a year, thanks to the known equivalence (Table 5).

Thus, the electricity coming from animal breeding sewage would be equal to 3.6 TWh/year that means about 1.2% of the total consumption registered in 2005 and 7.2% of the production of renewable resources. Compared to the real quantity produced, equal to only 26 GWh, the enormous potential as yet unexploited is evident. This value is triple of the electricity produced in Italy from biogas, coming from all the raw materials from which it can be obtained (1.2 TWh).

The quantity of heat, on the contrary, would be more than 7 TWh/year, corresponding to roughly 29 000 TJ/year, 21% of the total production from renewable sources in 2005. Considering the economic obstacles of heat transmission, this quantity is used in the same breeding farm. About one half is lost, the remaining part is used to both feed the gasification process (30%) and heat the sheds and homes (70%).

It is clear that these values in themselves represent a maximum quantity which is highly unlikely to come about, since, as known, the biogas yields can vary in proportion to techniques used both in the project phase and in that of digestion, to the types of subsoil (only zootechnical effluents or vegetable material mixtures) and to the ways of feeding both micro-organisms and livestock. To these, the logistic difficulties of finding raw material and all the legislative and economic problems must also be added which today hinder the wide scale spread of such plants.

4. Technical-economic and legislative aspects

In Italy, there are more than 100 biogas plants for zootechnical sewage (data related to 2006) which, as already mentioned, represent only a small percentage compared to the wide-ranging potential provided by this sector. The majority of these structures is small and located on the zootechnical farms: they are simplified, low cost systems, built by putting a tarpaulin over a large tank into which the sewage is conveyed. The biogas collected is pumped to an engine which produces electricity [31]. Over the last 3 years, interest has been shown towards the co-digestion of breeding farm effluents with energy crops; this has led to an increase in already operative facilities and/or those under construction and/or in the project phase [29].

Table 3
Indicative yield in biogas from animal sewage (m^3/t OM)

Type of sewage	% DM	% OM	Biogas yield m^3/ton (DM × OM)
Cattle	6–11	68–85	200–260
Swine	2.5–9.7	60–85	260–450
Poultry	10–29	75–77	200–400

Table 4
Conversion index

Type of sewage (1 ton or 1 m^{3}*)	Average biogas (m^3)
Cattle	15.0
Swine	15.6
Poultry	44.5

* It has been considered 1 ton = 1 m^3 for convention, supposed that the absolute specific gravity is 1 kg/m^3 like water at 4 °C as reported in the most of the references.

The delay on the part of Italy, when compared to other European nations is therefore questioned: as shown by the calculations carried out, the cause is not attributed to a question of resources thus, it is essential to understand what the technical-economic and legislative obstacles are, which so hinder Italian development in this direction.

Therefore, it is necessary to take into account the extremely complex administrative processes which are unnecessarily complicated and disorganised, above all for small-size plants, which concern the issue of a series of authorizations and feasibility studies both in the creative phase of a proposed project and, thereafter, in its preparation and realisation. In addition, on a local level, there is a lack of pre-planning of the designated areas where the biogas plants are to be built. Lastly, the national regulation, relative to incentives for the development of renewable resources, is still too sketchy and inadequate, when compared to those of other European countries, for example Germany. In fact, in this country, thanks to the FFT (Fixed Feed in Tariffs) system adopted, the fixed price for electric energy from biogas reaches 21.5 c€/kWh for 20 years, also accompanied by substantial public contributions to investments [15].

In Italy, where the TGC (Tradable Green Certificates) system has been adopted, the situation appears less encouraging: in fact, it is impossible to receive the “Green Certificates” when the biomass plants have been built using incentives of capital expenditure; moreover the duration is limited to 12 years (8 years plus 4 at 60% of the produced electricity) (Decrees of 24 October 2005 [32,33]; Legislative Decree No 152 of 2006 [26]). Indeed, they cannot be accumulated with “White Certificates”, unless for a cogeneration plant for teleheating (Legislative Decree No 387 of 2003 [22]; Law No 239 of 2004 [34]). All these factors influence the decisions related to the installation of an anaerobic digester, above all, among the small and medium-sized zootechnical farmers, who are unwilling to bear the high costs of construction financed privately.

The technical difficulties of plant management, along with high maintenance costs, above all for the more complicated installations, though more efficient, the finding of the adequate

Table 5
Production potential of biogas, electricity and heat in Italy deriving from zootechnical sewage

Type of sewage	Total quantity of sewage Mm^3/year	Biogas Gm^3/year	Electricity Wh/year	Heat TWh/year
Cattle	68	1.0	1.9	3.8
Swine	38	0.6	1.1	2.3
Poultry	7	0.3	0.6	1.1
Total	113	1.9	3.6	7.2

Table 6
An example of calculation concerning installation cost for a biogas plant (5000 m^3 of animal sewage plus 1000 m^3 of co-substrates; 43 kW installed capacity)

	Size	Unit	Minimum cost (€)	Maximum cost (€)
Digester	460	m^3	17 000	36 000
Post-digestion tank	539	m^3	20 500	29 500
Biogas storage tank	106	m^3	3500	8500
CHP unit	43	kW	27 000	73 000
Insulation	17.5	m^3	6378	10 168
Connection to thermal plant	72	kW_{th}	5000	5000
Blade pumps (kW)	3		3000	3000
Immersion mixers (kW)	11		6800	6800
Torches	143	kW_{th}	0	10 000
Heat exchanger for digester	72	kW_{th}	15 000	15 000
Other elements of safety			7100	11 100
Pre-mixing			25 000	25 000
Co-substrates tank			0	10 000
Other components (pipes)			4702	5062
Civil works			0	15 000
Partial total			143 980	276 130
Engineering works (%)	5–10[a]		7199	27 613
Total installation costs			151 179	303 743
Project management			5000	15 000
Total costs			156 179	**318 743**

[a] Percentage of components cost.

Table 7
Calculation example of installation cost for a wind plant of 20 MW installed capacity

	Size	Unit	Cost (€)
No. 10 turbines	2	MW	16 800 000
Civil works			780 800
Electrical infrastructure and grid connection			1 636 800
Others (installation, project management, insurance, legal costs, etc.)			2 595 200
Total costs			**21 812 800**

sewage quantity at a low cost, often located far from the "energy" site, and the need to have hectares of land (owned by the breeding farm or not) for obligatory spreading of the digested sewage obtained, which often influences the size of the plants (max 150–200 kWh), complete this less than favourable portrait of biogas production from zootechnical effluents in Italy.

For a clearer understanding of what has been said thus far, it is necessary to mention that the installation costs of a plant can vary according to the installed capacity, between 2500 and 7500 Euro for each kW installed or 250 and 700 Euro for each m^3 of digester, according to the presence or not of a scale economy. An example of calculation, aimed to show what previously said, is reported in Table 6. The costs of the main biogas plant components (such as digester, post-digestion and biogas storage tanks, CHP unit and auxiliary facilities) and of the planning have been considered. Supposing 5000 m^3 of animal sewage plus 1000 m^3 of co-substrates (vegetal biomass) and 43 kW installed capacity, the cost for each kW installed can consequently vary between 3600 and 7000 Euro, while the cost of digester can vary between 335 and little more than 650€/m^3, according to the lowest and highest costs estimated on the base of different component characteristics [29].

These values, when compared to those concerning wind power, are rather high. In fact, they range from 900 to 1200 Euro for each kW installed (Table 7; [31]). Therefore, it is not by coincidence that today wind energy represents the most competitive renewable source among the existing second generation ones (solar, photovoltaic and biomass). Further confirmation of the above comes from the comparison between the price of electricity produced from different types of energy plants fuelled by renewable resources to produce both heat and electricity (Fig. 8, elaboration of data from Ref. [35]).

In this case too, the cost of electric kWh produced from wind energy is the most competitive of all, ranging from 4 to 8 c€ according to wind velocity (6–7 m/s for land shore wind and 7.5 m/s for offshore wind) and, therefore, closer to the values of fossil fuels (less than 4 c€/kWh). The value of biomass, on the other hand, if used to produce heat (by means of direct combustion) is less than the value of wind power (1–6 c€/kWh); but, if used to generate electricity (as in the case of biogas in CHP systems) reveal that the costs are far from competitive compared to fossil sources (3–12 c€/kWh).

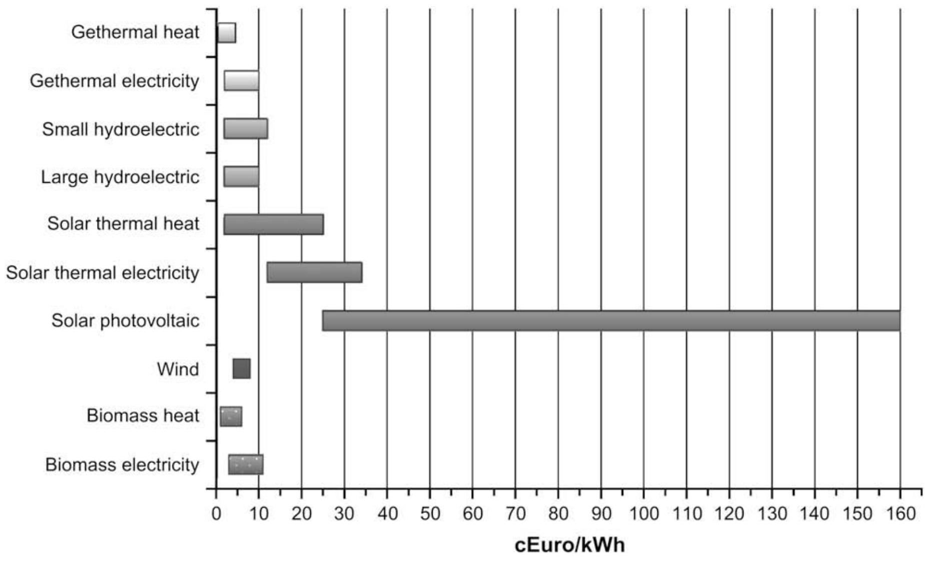

Fig. 8. Cost comparison of kWh produced from different renewable source technologies.

Therefore, the convenience in realising an anaerobic digestion plant to produce biogas becomes feasible when installation costs are amortized within a period of 4–7 years. This is possible only if one has benefited from Green Certificates (12.5 c€/kWh in 2006) [36] and the sale of electric energy at favourable prices (9.5–8.0 c€/kWh). Decision of the Authority for electric energy and gas No 34 of 23 February 2005 (Table 8; [37]). In order to demonstrate what has been said, Table 8 shows the calculation of costs and benefits related to plant installation described in Table 6. Total investment cost is supposed to be the average value between the lowest and highest costs previously estimated. Consequently, annual investment cost equals total investment multiplied by annual interest rate (usually for the same period of the technical life cycle of the plant, on average 15 years). Besides, this value will be reduced by a 30% annual subsidy.

Annual benefits, on the other hand, come from the sale of 80% of electricity produced (the remaining part is directly used by firm) and the sale of the Green Certificates (without electricity necessary to make the digester work, on average 5%). They also derive from savings due to the heat production (50%), from savings on chemical fertilizer, thanks to the use of digested slurry obtained from plant, which has better qualities compared to common manure. The payback period, that is the period necessary to amortize a loan, will be given by the ratio between the total investment cost (without subsidy) and the addition of annual profit to the annual investment cost. In this study it is estimated at almost 4 years.

Table 8
An example of economic analyses concerning a biogas plant (5000 m^3 of animal sewage plus 1000 m^3 of co-substrates; 43 kW installed capacity)

	Method of calculation	Example	€/YEAR
Costs			
Annual investment cost	Total investment cost × subidy of 30% × annual percentage rate	237 500€ (1–30%) 9.6%	15 960
Use and maintenance of digester	Total investment cost-maintenance of CHP × 3%	(237 500€–50 000 €) 3%	5625
Use and maintenance of CHP	Working hours/year (0.8–1.1)€/h	7500 h/year × 0.95 €/h	7125
Insurance and taxes	Total investment cost (0.5–1%)	237 500€ × 0.75%	1781
Manpower	Total hours/day × 365 (5–20 €/h)	0.5 h/day × 365 days × 12.5	2281
Substrates cost	Purchase and transport cost	3 €/t/year × 1000 ton	3000
Diesel for engine	Installed capacity kW × 72€/kW	43 kW × 72€/kW	3096
Total costs per year			**38 868**
Benefits			23 220
Electricity sale	Installed capacity (kW) × working hours – 20% × electrical price	43 kW × 7500 h − 20% × 0.09 €/kWh	36 765
Green certificates sale	Installed capacity (kW) × working hours × − 5% × green certificates price	43 kW × 7500 h × −5% × 0.12 €/kWh	6475
Utilized heat	CHP heat (GJ/year) × utilized heat% (5–15) €/GJ	1295 GJ/year × 50% × 10 €/GJ	2500
Fertilizer saving/improved quality of animal slurry	Animal effluents (t/year)saving(€/t animal effluents)	5000 t/year × 0.5 €/t	68 960
Total benefits per year			**30 092**
Profit per year	(Benefit–cost) per year	(68 960–38 868) €/year	3.6
Pay-back period (years)	Total investment cost (1–30%)/(profit + investment cost) per year	237 500 (1–30%)/(30 092 + 15 960)	

Positive signals, however, come from some areas in Northern Italy (Lombardy and Emilia-Romagna), affected by the presence of several intensive breeding farms. The respective regional bodies have, indeed, allocated some financing (capital expenditure) in favour of the single agricultural farms or the associated ones, the cooperatives and the consortium among private citizens, to produce biogas from field and from breeding. Only in Lombardy 57 new plants will be created, even if simple, 12 of which are already operative (February 2007) or almost. The maximum contribution distributed is 30% of maximum admissible expenditure and is constituted by an allowance on the capital quota and by a regional contribution on the interest rate (Regional Decree 8/3908 of the 27/12/2006 [38]).

5. Conclusions

Italian production of biogas from animal waste in 2005 was equal to 26 GWh, representing only a small percentage (2.2%) of the total biogas produced from wet biomass. However, the analysis carried out highlighted, as of 1991, a steady annual increase, equal to 1.36 GWh attributed to the spread of simpler anaerobic digestion technologies and to the issuance of laws supporting renewable sources.

From calculations on the total amount of available animal sewage in Italy, equal to 132 Mm^3/year, estimated potential production of biogas is approximately 2.2 Gm^3/year which, once transformed in energy, represents 8% of production of electricity and 21% of thermal energy deriving from renewable sources, relative to 2005. These figures are theoretical since, as known, biogas yields may vary based on technical, logistical and economic factors: nevertheless, in Italy zootechnics could represent a driving sector in large scale production of biogas.

Limits to short-term development of the use of animal sewage as an energy resource are represented by: the current anaerobic digestion technologies which are not sufficiently effective as to currently render the cost of energy produced competitive, compared to fossil fuels; and administrative procedures which are both dispersive and complex, above all in the case of small-sized plants.

Thus, a legislative reform would seem opportune in order to make incentives for energy production from biomass more efficient and economically advantageous for investment in this sector.

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