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Features and Sustainability Components of a Laboratory of Analysis for Biogas Plants

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Abstract

The purpose of this work is to examine the economic and environmental sustainability of a laboratory that carries out the necessary analyses for biogas production from biomass. The results emerging from the Business Plan were related to the state of facilities existing in the Lombardy region. The limits and potentiality of the sector were identified by means of the BEP Model (Break Even Point) in the geographic area of reference. The most interesting final results have revealed both the undeniable potential of the sector and its strategic role within the framework of the sustainable energy objectives of Europe 20-20-20. The network of laboratories, in fact, constitutes a guarantee and an element of security for the effective reduction of greenhouse gases.

Abstract

Lo scopo di questo lavoro è quello di esaminare la sostenibilità economica e ambientale di un laboratorio che sviluppa le analisi necessarie per la produzione di biogas da biomasse. I risultati emersi dal Piano Industriale hanno riguardato lo stato delle strutture esistenti nella regione Lombardia. I limiti e potenzialità del settore sono stati identificati mediante il modello BEP (Break Even Point) nell'area geografica di riferimento. I risultati finali più interessanti hanno rivelato sia il potenziale innegabile del settore sia il suo ruolo strategico nell'ambito della sostenibilità degli obiettivi energetici di Europa 20-20-20. La rete di laboratori, infatti, rappresenta una garanzia e un elemento di sicurezza per l'effettiva riduzione dei gas serra.

Keywords: biogas, raw material, business plan, laboratory, biogas production from biomass.

1 – Introduction

The anaerobic digestion is a process that occurs naturally in anaerobic conditions. To enhance and accelerate the biogas production it is necessary to ensure an optimal environment for the bacteria used, monitoring all the relevant parameters through appropriate physical-chemical analysis in order to detect process failures promptly, for example, excessive acidification or the lack of nutrients (Krakat et al., 2011; Chen et al., 2008). The aim of this study is to assess the economic feasibility of an analytical laboratory, which supports the efficient management of biogas plants. The information obtained from contacts with professionals and from literature analysis has identified

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Cremona as the suitable potential site for the laboratory location in Italy[1].

In this area, a new agro-industrial energy district is being consolidated based on a considerable presence of cattle farms and agro-food industries, which provide organic waste to anaerobic digestion plants, throughout the whole year.

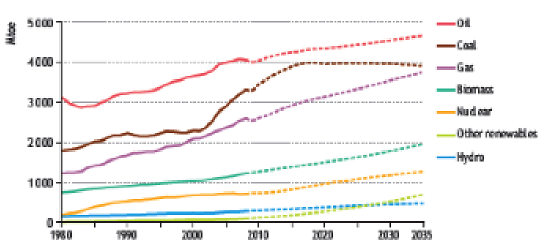
A laboratory should perform routine analysis to carry out the process and also support the manager with quantitative and qualitative determination of the products fed into the facility.

2 – Framework (of situation)

The persistent energy demand, that needs to be satisfied in terms of environmental sustainability, requires a new approach to energy consumption and the diversification of sources with particular emphasis on renewable energy.

Most of the consumed worldwide energy is still produced by fuel oil and coal, a small percentage is generated by nuclear power plants, while the contribution from renewable sources energy is still almost negligible (**Figure 1**) (Deublein and Steinhauser 2008).

Fig. 1. Reference scenario for the world demand of primary energy by fuel (Mtoe = million tonnes of oil equivalent) (World energy outlook 2010)



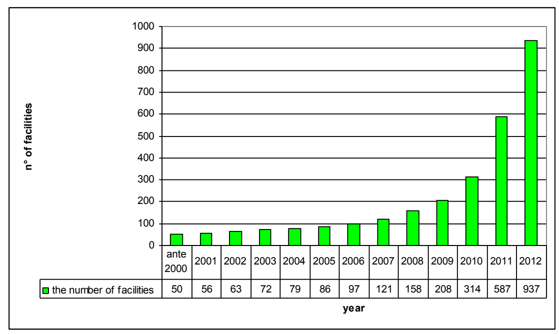
The EU policies concerning renewable energy systems (RES) have set a goal of supplying 20% of the European energy demands from RES by 2020. Among the renewable energies, the biogas would originate at least 25% of bioenergy for European countries: in particular the biogas, produced from farming wet organic materials, will play an important role in the bioenergy field. The biomasses used for these technologies are: animal manure, whole crop silages, wet food and feed wastes, etc. (Holm-Nielsen et al.2009).

The limit of most renewable energy is related to the discontinuity of production, so to optimise the use of these sources it is necessary to optimise a mix of technologies that will allow overcoming the single limits.

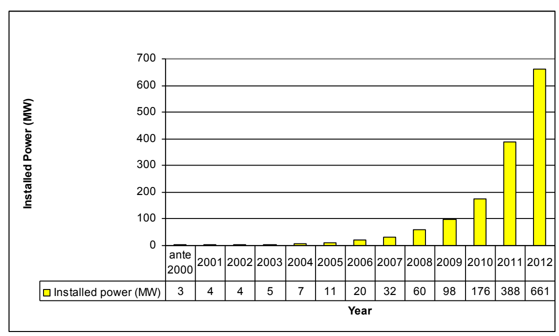
The maximum efficiency depends also on climate and geographical conditions, so it must be related to the location of individual plants (Deublein and Steinhauser 2008).

In Italy, the importance of the biogas production has increased significantly in the period 2008-2012; this is clearly exposed in **Graphs 1** and **2**, which show an almost exponential growth both in number of plants and installed power.

Graph 1. Trend of plants number operating in Italy (Piccinini 2013)



Graph 2. Trend of installed power (Piccinini 2013)



In five years the plants number has increased from 158 to 937 (with a percentage increase of 493%), while the installed capacity shows an even greater increase from 60 MW installed in 2008 to 661 MW in 2012 (over 1000% increase). These data show a further important element to delineate the characteristics of the sector development, linked to the affirmation of medium and large size plants. In 2006, for example, the average installed power was about 20 kW, which represents substantially experimental systems only for internal plant use.

Considering the new installed capacity (601 MW) and the number of new plants (779) from 2008 to 2012, the average installed power for single plant settles around 770 kW, which represents industrial

[1] In Italy, laboratories dedicated to these analysis are: SCHMACK BIOGAS (Bolzano), MT-ENER-GIE (Padova), BTS (Porto Mantovano, MN), CHELAB (Piacenza), NEOTRON Analytichal and Tecnichal Service (Modena).

facilities able to put into the network a significant share of the energy produced, after satisfied the factory energy needs (Piccinini, 2013).

Figure 2 shows the distribution of plants in the Country that points out a lack of homogeneity between the northern regions and the rest of the Country.

Fig. 2. The regional distribution of agricultural and livestock biogas plants in the Country for the year: 2012 (Piccinini 2013)

Table 1. Data related to the number of bovine units raised in Italy (derived from: Cordoni, Pignone and Cordoni, Percivalle)

	1998	2000	2002	2005	2007	2010
Piemont	1,026,900	818,798	858,281	785,000	829,980	815,613
Lombardy	**1,852,300**	**1,606,285**	**1,760,053**	**1,545,000**	**1,692,649**	**1,484,991**
Veneto	1,057,800	931,337	992,658	860,000	970,130	756,198
Emilia-Romagna	747,300	627,964	653,226	609,000	623,980	557,231
Total of 4 region	**4,684,300**	**3,984,384**	**4,264,218**	**3,799,000**	**4,116,739**	**3,614,033**
National total	7,240,000	6,049,252	6,695,535	6,300,000	6,576,781	5,592,700

Table 2. Data related to the number of swine units raised in Italy (derived from: Cordoni, Pignone and Cordoni, Percivalle)

	1998	2000	2002	2005	2007	2010
Piemont	751,000	923,700	989,163	1,010,000	977,015	1,112,083
Lombardy	**2,961,500**	**3,839,077**	**3,928,750**	**4,121,000**	**4,132,342**	**4,758,963**
Veneto	545,600	699,374	753,044	757,000	736,731	798,242
Emilia-Romagna	1,681,700	1,555,344	1,679,793	1343,000	1,630,060	1,247,460
Total of 4 region	**5,939,800**	**7,017,495**	**7,350,750**	**7,231,000**	**7,476,148**	**7,916,748**
National total	8,090,000	8,603,141	9,166,258	9,300,000	9,272,935	9,331,314

From a total of 937 plants at least 882 (94%) are located in six regions in the North, particularly in the Po Valley area, which holds the majority of livestock production in Italy, **Tables 1** and **2** (Cordoni and Percivalle 2008; Cordoni et al. 2009). One of the economic instruments that have facilitated the development of the sector is certainly the introduction, from 2008, of incentives for the production of electricity from renewable sources. (GSE 2010).

The Official Journal published on July 23, 2009 the Law no. 99/2009 fixed in the art. 42 at € 0.28 / kWh the all-inclusive fee for biogas generated electricity.

Moreover, in accordance with the Law no. 266/2005 the production of electricity and heat energy from biogas is considered agricultural activity *(Finanziaria 2006),* art. 1 comma 423 edited by art. 2 quater of the L. 81/2006:

> *The production and transfer of electricity and heat energy from renewable agroforestry and photovoltaic by farmers are connected activities, according to art. 2135, paragraph 3 of the Civil Code, and are considered activities producing agricultural income.*

In this way, the legislator recognizes to biogas produced from farms the same benefits provided for all land-related activities in order to encourage the diffusion of the systems.

In Italy, the anaerobic digestion sector is the one showing the largest increase in the number of plants.

2.1 – *Specifications of a biogas plant*

Biogas is produced from the digestion process of organic waste in landfills, but also from the anaerobic digestion of animal manure, agro-industrial by-products, sewage sludge and dedicated crops (Lombardi and Tricase 2008). The biogas plant production is designed to encourage the natural process of anaerobic digestion (AD).

AD is a biological process which transforms the organic matter into gaseous fuel in oxygen absence. The complex organic substance is composed of carbohydrates, fats and proteins; it is converted into biogas by the joint action of several strains of anaerobic microorganisms.

Biogas consists mainly of methane (50-80%) and carbon dioxide (Persson et al. 2006), may also contain hydrogen sulphide, ammonia and nitrogen (Lombardi and Carnevale 2013) in amounts depending on the raw materials used in the digester. Generally, anaerobic digestion converts organic waste into two categories of valuable products: the biogas and the digested substrate (digestate). The biogas is a renewable fuel used to produce green electricity, heat or vehicle fuel (Holm-Nielsen et al.2009). The digestate can be directly used as starting material for preparing high quality compost (Scano et al. 2014).

2.2 – *The raw material*

Originally anaerobic digestion was used primarily for manure, sewage and sewage sludge treatment. With the new agricultural policies supporting biogas plants, other feedstocks are added to "traditional" substrates in order to improve the efficiency of the plant, because often manure and animal excrements have low energy content (Reise et al. 2012). Biomass used for anaerobic digestion must have a C/N ratio around 30 and moisture content greater than 30%.

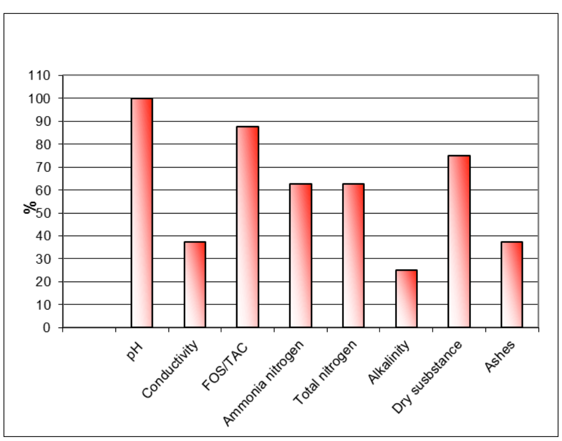
Biogas can be produced from nearly all kind of biological feedstock types, the largest resource is represented by animal manure and slurries from cattle and pig production units as well as from poultry, fish, fur, etc (Holm-Nielsen et al.2009).

The quantity and quality of the raw material, together with the digestion system and the retention time, influence the biogas composition, the rate of degradation, the yield, and the cost of methane production (Tricase and Lombardi 2008, Weiland 2010).

2.3 – *Users census*

The information received from managers of biogas facilities shows that, in Italy, most of the analysis is performed in Lombardy and Emilia Romagna.
Analysis carried out on material to be digested is distributed as shown in **Graph 3**.

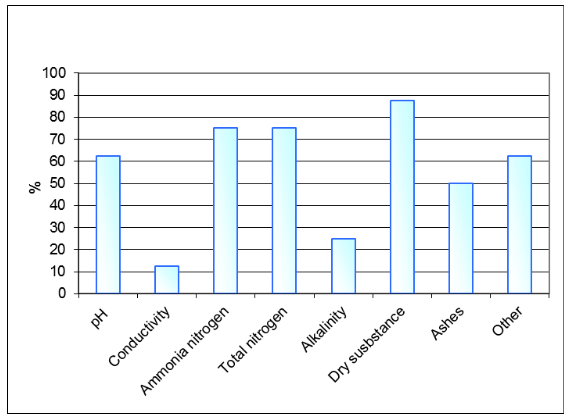
Graph 3. Distribution analysis of material to be digested



Some plants, in addition to the analysis shown in the graph, also perform data on: Volatile Fatty Acids, trace elements, water, HAc equivalent, not reported graphically.

The most tested parameters in the digestate analysis are shown in **Graph 4**: pH, FOS/TAC[2], and dry matter. Several plants also test: phosphorus, potassium, organic matter, organic carbon, humic acids, heavy metal, volatile solids on a dry matter, COD (Chemical oxygen demand), ratio C/N.

Graph 4. Distribution analysis of digestate



3 – Business plan for the realization of a laboratory aimed at supporting biogas plants.

In the start-up phase of the business, it is essential to have a clear picture about the set of short-term and long-term funds required for an efficient management. These loans are used in the purchase of production factors such as the backbone of the company and the raw materials. It is also important to investigate the characteristics of the monetary cycle, the return of investment and financing time, the liquidity and profitability along the whole supply chain.

To achieve the best results of management, all business functions - manufacturing, commercial, administrative, financial, and organizational - must be shared with members working in the organization, not only for what concerns the production side, but also for what regards the conception of the business idea, upon which the organization itself is based.

It is the company's mission, which is the culture / philosophy that the company applies to its activities, both within the core business and in the empathic relationship with the audience, because by means of a slogan or phrase identifying the organization may be

[2] FOS = Flüchtige Organische Säuren TAC = Totales Anorganisches Carbonat

better known, then remembered and "searched" on the market.

Once the mission has been outlined, follows the strategic planning phase, namely the establishment of long-term objectives and the amount of resources needed to achieve them.

The objectives relate to:

– *profitability* - both in terms of operating profits and as an increase of company

– *dimensional development* - quantification of the market, potential new markets

– *leadership* - not only excellence in business performance, but also attention towards sustainable technological and management innovation

– *social responsibility* - accountable to community

– *financial balance of the structure* - harmony between private capital and debt financing.

The planning will then be examined, generally for a period of at least five years,consisting of 5 annual programs, each of which investigates the short-term objectives (12 months)in order to achieve the final objectives of the Business Plan.

3.1 – *Costs for the implementation of the laboratory*

First of all, it is important to define the plan of economic feasibility for the implementation of a laboratory performing chemical-biological analysis for biogas plants. Preliminary survey shows that the costs related with the activities of the first year of the laboratory amounted to approximately € 162,000 (**Table 3**), including the amortization rate regarding the purchase of long-term equipment, the consumption material and the management costs.

Table 3. Repayment plan of the loan

Years	Annual quota	Interest quota	Capital quota	Paid debt	Remaining debt
0					120,000.00
1	15,540.55	6,000.00	9,540.55	9,540.55	110,459.45
2	15,540.55	5,522.97	10,017.58	19,558.13	100,441.87
3	15,540.55	5,022.09	10,518.46	30,076.58	89,923.42
4	15,540.55	4,496.17	11,044.38	41,120.96	78,879.04
5	15,540.55	3,943.95	11,596.60	52,717.56	67,282.44
6	15,540.55	3,364.12	12,176.43	64,893.98	55,106.02
7	15,540.55	2,755.30	12,785.25	77,679.23	42,320.77
8	15,540.55	2,116.04	13,424.51	91,103.74	28,896.26
9	15,540.55	1,444.81	14,095.74	105,199.48	14,800.52
10	15,540.55	740.03	14,800.52	120,000.00	0.00

This paper will focus only the economic components, extrapolating from the Balance sheet just the cost items that are functional to the current study.

In the start-up phase is necessary to assess the costs related with a physiological financial exposure.

Assuming an own capital of 42,000 Euro, and raising the difference from an institutional lender (bank or financial institutions), we have developed a financing plan based on the share of capital to be repaid in a specified period (duration of the loan) plus the interests on loan capital. It is possible then, assuming a time of funding of 10 years, at an interest rate of 5% per year, to draw up a table with the specifications of a refund (**Table 4**) composed of a constant annual amount (EUR 15,540.55) in which the share of capital increases and at the same time the interest quota decreases (American method), as follows:

$$Qa = 120000 * \frac{0{,}05 * q^{10}}{q^{10} - 1} = 15540.55 \text{ euro}$$

where:

Qa = annual constant quota = Capital + Interest

$q = (1 + i)$ the discounting factor where $\boldsymbol{i}$ is the interest rate of 5%.

Table 4. Laboratory start-up costs

Start-up costs	Euro
Laboratory (furniture and analytical equipment)	65,000
Legal fees	5,000
Alarm system	3,000
Various permissions	5,000
TOTAL	**78,000**

The annual component of the fee (capital + interest) is 15,540.55, but in the prospectus of operating costs (**Table 5**), the interest share for the year will be considered, amounting to € 6,000.00 for the first year.

Table 5. Costs allocated to the activity for a full year

Operating costs	Euro
Interest expense on the loan	6,000
Share of amortization of long-term costs	18,080
Lease of warehouse 80 m^2 (rent hypothesis), according to law for gas, enel, ACE (Energy Certification).	15,000
Bills concerning the supply of Gas, Electric Energy, Water, Telephone.	3,000
Consumables (stationery, gloves, paper, other)	1,000
Disposable material for laboratory.	1,000
Reagents	15,000
Equipment for Personal Protection and Safety	1,000
Staff	102,000
Insurance (third party liability, fire, theft, professional)	3,200
Bank (account expenses)	500
Contingent liability (unexpected)	2,220
Total	**162,000**

The quota capital will be included in the component "loans" in the section Debt of Balance sheet.

Supposing renting rather than buying a structure already equipped with the expected rules as a plant, to make the laboratory operational provide further costs, as described in Table 5: for the furniture and the proper equipment, whose total cost is estimated at € 65,000, divided as follows: € 27,000 for laboratory equipment (desks, cabinets, stools, trash cans, computers, etc.), € 38,000 for the necessary instrumentation (pH meter, conductivity meter, stove, FOS / TAC, distiller for "Kjeldal 129", refrigerator and much more). The costs involved in alarm system, legal fees and various permissions, amounting in € 13,000, are detailed in Table 5.

Start-up costs reported in Table 5 should be placed in the statement of tangible and intangible assets fixed in the Balance sheet. Of these items is included in *operating costs* (Table 3), the annual amortization charge of € 18,410.00. The costs allocated to the activity of a full year (accounting period) are shown in detail in Table 3. For simplicity in data processing, we assume that the management tasks begin the 01/01/ n.

The amount for the bills concerning the supplies of gas, electricity and water, as well as the costs of insurance and bank fixed fees, were calculated using estimates derived from rates of the territory concerned. Also in Table 3 is the "Share of amortization of long-term Costs", for which the annual depreciation rates are taken from the tables for companies of this sector as described in the Decree of 31/12/1988. [*Coefficienti di ammortamento del costo dei beni materiali strumentali impiegati nell'esercizio di attività commerciali, arti e professioni. (Pubblicato in Gazzetta Ufficiale n. 27 del 02/02/1989)*].

The item "Staff" includes the costs related to: 1 analyst (part time), 2 laboratory technician and a business consultant (**Table 6**).

Table 6: Staff costs

Staff costs [3]	Unit price(euro)	Number	Total
Analyst	45,000	1	45,000
Laboratory technician	25,000	2	50,000
Accountant [4]	7,000	1	7,000
Total			**102,000**

The item "Personal protective and safety devices" includes: individual protective devices, first aid cabinet, shower eyewash, fire extinguishers and equipment maintenance log (compulsory since 1994 with the D.Lgs. 626/94 Art. 13, D.P.R. 12/01/'98 n° 37 art. 5 and subsequent D.Lgs. 81/2008), programmed update for risk control and the prevention of accidents at work.

4 – Certification and accreditation of a laboratory

To complete the costs associated with the laboratory management, it is necessary to consider the opportunities and challenges of the certifications ISO 9000 and ISO 14000 families related to Quality and Environmental protection, respectively.

Increasingly, Quality certification is an essential element for proper positioning on the market, and an opportunity to ensure optimization of relations with local authorities, who are recipients of analyses and checks carried out on plants.

The quality management system implementation involves the resources investment especially in the start-up phase, aimed at building a *Quality culture*, which is shared by all staff employed in the laboratory. Through proper application of procedures implemented in the Quality manual, the laboratory activity is developed from the point of view of efficiency and effectiveness, which generate a positive impact in terms of savings. The immediate economic return is to minimize the costs related to non-quality (duplication of processes, protocol errors, accidents, occurring to workers, etc).

The Environmental certifications related to series ISO 14000 are an important tool for communicating with stakeholders, engaged in environmental protection, and with the local community hosting the laboratories on its territory. They ensure that the activity is carried out in compliance with the minimum environmental impact, in particular relative to the management of the process output.

5 – Discussion

The limited number of laboratories dedicated to this type of analysis and the continued installation of new plants, shows the presence of a sector which has not been adequately explored yet.

This offers the opportunity to start a sustainable network of structures that implement work effective protocols to support the production facilities and biogas valorization.

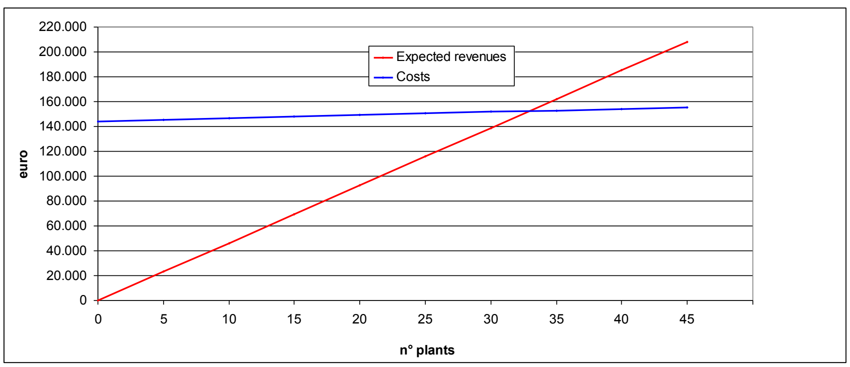
The variability and particularly the complexity of the parameters associated with the economic analysis, limit nowadays, the possibility to develop a business plan pattern of general validity.

The effort of data synthesis at different levels of technical and productive cycle, allowed introducing in this paper a first feasibility model able to describe in detail the common and essential characteristics, focusing on the technical information about the sector of chemical and environmental education.

The economic sustainability of the laboratory was evaluated applying the Break Even Analysis, in order to derive the break-even point (Manca, 2004) for the number of plants for which it is necessary to perform the analysis required for ordinary management (**Graph 5**).

The fixed and variable costs were considered in relation to a year of activity and they were calculated as described above, then they were compared to the expected revenues for each plant, with reference to the standard package of routine analysis, described in the previous pages, neglecting the analysis carried out annually, as not significant for the purposes of this model.

Graph 5. Break even point



Routine analyses are: pH, FOS / TAC (volatile organic acids/alkaline buffer capacity), ammonia nitrogen, total nitrogen, dry matter. These analyses should be carried out twice a week and their market price settles around € 44.50.

For economic sustainability, the Graph 5 highlights the need to have at least a number of facilities that exceeds 33 units. The characteristics of the represented curves show the predominant weight of fixed costs compared to variable costs.

As already known, the preponderance of such costs highlights on the one hand a poor business flexibility but, however allows, once overcome the BEP, to have an area of profit that quickly becomes significant, even with a modest increase in the number of plants. In absence of an adequate surplus asset is impossible to achieve the goal of establishing a company that is a "*lasting economic institution*" (Zappa, 1956). Consequently, it is necessary to evaluate the large number of geographical distribution of plants to identify economically viable ways.

With reference to Lombardy where exists the largest number of plants for biogas production, **Table 7** shows an non-homogeneous state of affairs: the Province of Cremona could accommodate even two analytical laboratories dedicated entirely to the field, in the Province of Brescia at least 1 plant could be placed, in the provinces of Lodi, Mantua, Pavia the number of facilities is too close to the BEP, generating a potential income too reduced for economic sustainability.

The budget rigidity due to the clear preponderance of fixed costs shows a significant business risk serving only a single class of users.

Moreover, the economic principles on which are based the business strategy of medium and long term is not compatible with tight balance situations in the context examined, characterized by significant technological evolution regarding means and tools analysis, whose obsolescence is particularly rapid.

It is therefore preferable to think about the development of a branch within a laboratory that is also performing analyses for other categories of users.

Table 7. Number of facilities in the Lombardy region (Fabbri et al 2013).

Bergamo	11
Brescia	67
Cremona	130
Lodi	64
Mantua	55
Milan	8
Pavia	37
Sondrio	2
Total Lombardy	**374**

6 – Conclusions

The biogas sector shows a trend of continuous development and improvement of technological systems. This justifies completely the choice of new investments by laboratories interested in investing for the medium term (figures 2 and 3) in dedicated plants. These may be placed in a leadership position in emerging markets, acquiring and consolidating a functional know-how to support and develop the sector.

This activity which at the beginning could be added to the existing laboratories could grow significantly, in a context of renewable energy sources expansion related to the distributed micro-generation, promoted at European level as an environmentally sustainable strategy.

As the financial requirement is quite high, it would be desirable to look for resources dedicated to the European Union's young entrepreneurs.

A network of specialized stable laboratories, economically sustainable, is an important element of control and a guarantee of efficiency for the biogas plants management. This network of laboratories constitutes a support to the management engineering, to the power optimization and to the plant operation.

The economical sustainability of facilities depends on the sector efficiency and it is essential to lay the basis of a significant development. The environmental sustainability is expressed through the reduction of CH4 emission, which is a green house gas, according to the Kyoto Protocol.

Thus, the biogas collection system cannot be structured in an optimal way without the presence of laboratories, which is an element of guarantee to achieve the Europe 20-20-20 objectives.

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