PRODUCTION OF RENEWABLE ENERGY IN AGRICULTURE: THE CURRENT SITUATION AND FUTURE DEVELOPMENTS

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Abstract. *The role of agriculture in the field of energy is part of a wider framework of services that this sector can provide to the community, integrating the concept of multifunctionality already attributed to it. Whilst agricultural activity is an excellent means for protecting and enhancing the appearance of the territory, the production of agro-energy could become an opportunity for farmers to find new outlets, not only for their crops, but also for by-products and agro-livestock waste/slurry. In fact, energy production can be an important opportunity for farmers to diversify their business, broadening the prospects and scenarios for agricultural and livestock farms. The energy potential of a rural area through the use of biomass produced by agriculture will now be investigated in depth: the authors describe agro-energy production chains that specifically use biomass, ignoring other technologies (primarily photovoltaic and solar thermal) that can be developed, with profit, by the farmer, but which are not directly related to the traditional activity of a farm. Given a proven technology, the main problems for this energy chain are to be found in the procurement of biomass, costs of transport and management of biomass and digestate, and in the regulatory framework which is often difficult to interpret at the local level.*

The biogas chain will be examined in detail, especially in relation to the significant growth in the number of plants constructed. Through the study of the main features characterising the chain - procedure for authorization of plants, taxation of energy production, by-products of organic and agro-livestock origin and incentives and tariffs for energy production, - the economic sustainability of biogas production plants will be evaluated.

Finally the authors present a comparison between rates of incentive before and after 2012 in order to analyse the risks for the profitability of the chain.

Keywords: *economic evaluation; biomass; biogas; Italy.*

1. Introduction

In recent years there has been growing interest in the development of renewable energy due to the need to solve problems of increase in energy consumption and the instability of prices for raw materials of fossil origin, and because of concerns about pollution and its effects on climate change. In order to solve these problems there have been extensive studies into systems and processes capable of limiting the increase in "greenhouse" and so-called "climate changing" gases and, at the same time, to make countries increasingly independent from the energy point of view.

In Italy, similar considerations have taken on a special significance, precisely because of the

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increasing dependence on foreign energy (over 83% in 2009), the cost of energy and emissions harmful to the climate, all running counter to the objectives laid down at international level on the subject of global warming.

To tackle these issues, there is an increasing need to promote efficient long-term energy planning and to provide adequate public incentives for technological innovation and research in the context of improved efficiency in energy saving and technical alternatives to the consumption of fossil fuels.

In particular, the ongoing climate change will require greater commitment to take all possible measures to reach conditions of equilibrium and overall efficiency in the production and use of energy according to models of sustainability.

Faced with this scenario, the agricultural sector can play an important role in contributing to increased production of energy from renewable sources. Climate-related problems are directing agriculture towards new challenges and new opportunities, specifically in relation to its presence at local level, characteristic of the strategic activities of the sector.

In addition, agriculture can contribute directly to reducing net emissions of carbon dioxide (CO_2) and other greenhouse gases, both through the exploitation of various types of biomass for energy purposes, to be used as a substitute for fossil fuels, and through the adoption of agricultural practices that favour the accumulation of carbon in cultivated plants and the soil.

Indeed, the ability of plants to trap solar energy, converting and storing it permanently in the form of chemical energy is well known, as well as their ability to capture carbon dioxide from the atmosphere, retaining the carbon and emitting oxygen. In fact, in 1.0 g of dry matter there is about 0.5 g C which is obtained from 1.83 g of fixed atmospheric CO_2 (D. Coiante, 2010).

Therefore, the role of agriculture in the field of energy is part of a wider framework of services that it can provide to the community, integrating the concept of multifunctionality that has been attributed to it. Whilst agricultural activity provides an excellent opportunity to protect and improve landscape, the production of agro-energy could become an opportunity for farmers to find new outlets, not only for their crops, but also for by-products and agro-livestock waste/slurry. In fact, people are aware that there cannot be a single rapid replacement of existing energy resources with other more sustainable ones, and that the possible complementarity of new renewable energy sources (RES) must be studied in relation to the vocation of the territory in which its development is planned.

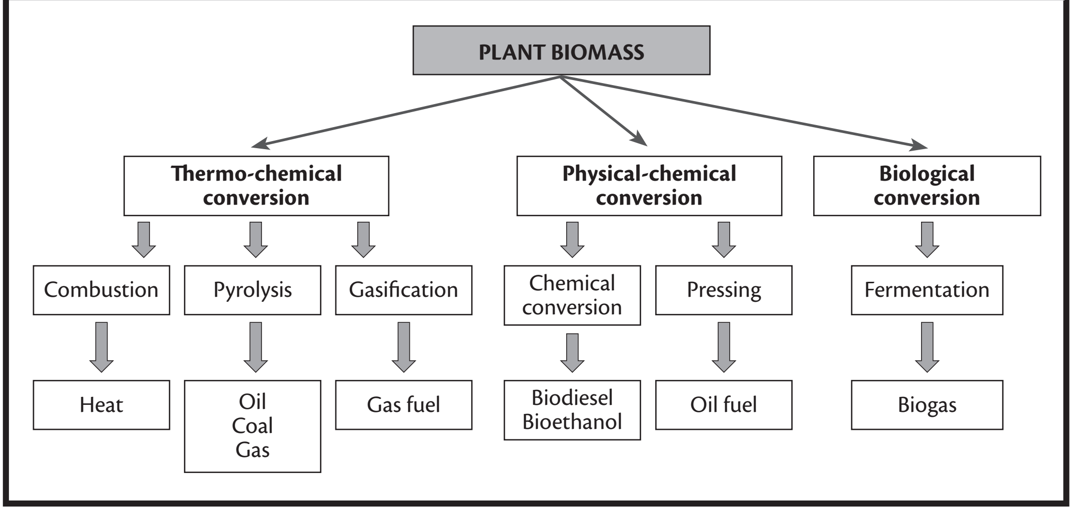
2. Agro-energy production: biogas production chain

From the foregoing it can be said that energy production provides an important opportunity for farmers to diversify their business, broadening the prospects and scenarios for agricultural and livestock farms. The energy potential of a rural area through the use of biomass produced by agricultural activity will now be investigated in depth: we will therefore describe the agro-energy production chains using biomass specifically, while ignoring other technologies (primarily photovoltaic and solar thermal) that can also be developed profitably by the farmer, but which are not directly related to the traditional activity of a farm.

Raw materials of agricultural origin can be destined mainly for the production of electricity, heat or biofuels, depending on intrinsic characteristics, following a variety of transformation processes. As shown in figure 1, the main energy production chains that can be activated on a farm are as follows:

- **Chain for production of solid biofuels** (thermo-chemical conversion process);
- **Chain for production of biofuels** (physical-chemical conversion process);
- **Chain for production of biogas** (biological conversion process).

Fig. 1 - Energy production chains using agro-livestock biomass



In particular, the term biogas refers to a mixture of gases, consisting primarily of methane (50-80%), obtained from the anaerobic fermentation of biomass of plant and animal origin.

This process is performed by microorganisms capable of metabolizing organic substances with consequent production of gas. Compared to the production chains described previously, that of biogas involves the development of active microorganisms, therefore it is essential to achieve an optimal environment for them, and to maintain it over time.

The raw materials involved in the biological conversion process are as follows:

– Energy crops: such crops, referred to as "*dedicated"* to energy conversion, are essentially maize, sorghum, triticum, wheat, rye, etc.
– Manure: this biomass has particular importance in the biogas production process because it is waste that can be exploited, and it also contains a large quantity of micro-organisms which act as inoculum in the transformation of the substrate into biogas.
– Crop residues: these refer to residues from agricultural production such as maize stalks, straw, fruit waste, etc..
– Agro-industrial by-products: this is organic waste that is commonly produced in the processing of food products. These substrates have a high potential, but may be subject to seasonal availability or specific authorization (as for slaughterhouse waste).
– The organic fraction of municipal solid waste: this category includes numerous materials, difficult to classify and usable only on the basis of the directives on "waste".

Regarding the technology used, the main distinctions concern the total solid content in the biomass used and the temperature of the process. Digestion, therefore, can be defined as "wet", if the substrate has a total solid content less than 10% and "dry" if the percentage is greater than 20%. In the first case, the material used can be mixable and pumpable, while in the second case, the substrate is not mixable and special techniques are required for loading the plant. As regards the process temperatures, fermentation can be mesophilic, when the temperatures are kept between 38 and 40°C, thermophilic (between 55 and 57°C) or in psychrophilic (below 35°C, but this is uncommon). For each temperature, different families of microorganisms develop, suitable for carrying out the digestion process.

Typically, a wet digestion biogas plant with mesophilic operation, consists of one or more fermentation tanks made of steel or reinforced concrete, equipped with an internal heating system, a biomass mixing system and a gasometric covering capable of accumulating the biogas produced. A system of pipes delivers the gas to a purification complex, normally a chiller (or refrigerator) with a heat exchanger, for the elimination of water vapour, and subsequently to an internal combustion engine for the production of electricity. The motors used are able to recover the thermal energy deriving from the cooling system in order to heat the fermentation tanks and possibly other production premises or dwellings; in this case, the process is referred to as cogeneration.

The end product of the anaerobic digestion process is the digestate, which takes the form of stabilized organic matter (generally odourless) with organic and chemical characteristics derived from the substrate used as input to the system.

Faced with a proven technology, the main problems with this energy chain are to be found in the procurement of the biomass, costs for transport and management of the biomass and digestate and in the regulatory framework which is often difficult to interpret at the local level.

As mentioned, the current incentive rate of 0.28 euro/kWh of electricity fed into the grid (valid for plants built and in operation by 31/12/2012) has enabled the activation of large-scale power plants, also in those cases where it was difficult to procure supplies of the biomass necessary for the process, where most of it was purchased on the market and not produced directly on the farm. In these cases, the economic vulnerability of the plants increases, since their sustainability depends the economic parameters, which are unlikely to remain stable over time (rental cost of land, cost of the substrates on the market, costs for disposal of the digestate etc.), which have to be considered for at least 15 years, given the conditions for issuing incentive grants. On the basis of these considerations, and with the current reduction in the comprehensive rate, increasing attention has been focussed on the exploitation of waste raw materials to feed the digesters, and to size these according to the actual availability of substrates.

The biogas chain, which recently acquired an important role in rural areas, especially in relation to the significant growth in the number of plants constructed, will be examined in more detail below. In 2012, 994 biogas plants were recorded, corresponding to an output of about 750 MW of installed power (in 2012 alone, 350 were produced).

3. Reference Standards

The production of energy from biogas is subject to a complex legislative framework that is not always easy to interpret. This section summarizes the main aspects that regulate this energy chain, with reference to the legislation that authorizes and provides incentives for plants at national level (figure 2); in particular, the following aspects are considered:

– ***Authorization procedures;***
– ***Taxation of energy production;***
– ***Incentives for the production of renewable electricity*** (with particular reference to the Ministerial Decree of 6 July 2012).

Fig. 2 - Key regulatory elements for designing a biogas plant

Authorization	Incentives	Taxation	By-products
Simple communication: 0 - 200 Kw If the buildings are not altered	**to 31 December 2012** **Single rate 28 euro/KW/h**	The sale of electricity obtained from agricultural sources with matrix coming **mainly** from the farm, carried out by **farmers** is included as a **related activity**	**Min. Decree 3 December 2010 no. 205** **Leg. Decree 3 March 2011 no. 28** **Min. Decree 6 July 2012**
Simplified enabling procedure (PAS): 0 - 250 Kw In any case **0 - 999 Kw** In cogeneration	**from 1 January 2013** **Specific incentives for power and diet**	**Agricultural income** Determined on the basis cadastral rents for land (Art. 32, TUIR)	«... **by products include** (...): faecal and plant material from cutting and pruning as part of the maintenance of public and private green areas, or from agricultural activities, even outside of the place of production **and sold to third parties**, or used in plants to produce energy or heat, or **biogas** ...»
(C) Single authorization: Where the previous restrictions are not observed			
From 2013 plant with power > 100 KW must be registered in a national register. The sum of the installed power must not exceed the annual target			

3.1. Authorization procedures

The guidelines for authorization to construct and operate plants producing electricity from renewable sources were published in the Official Journal of 18 September, 2010 and inserted definitively in Legislative Decree no. 28 of 3 March, 2011, which implements the basic Directive 2009/28/EC on the promotion of renewable energy. The authorization process, followed by all Italian Regions, provides the following reference framework:

a. systems considered as freely constructed and subject to simple communication: in the case of installed electrical power <50 kW in a cogeneration scenario, or <200 kW if the property structure of the building is not changed;
b. plants that can be constructed through a simplified enabling procedure when the installed electrical power is <250 kW, or <1 MW in the case of cogeneration with heat recovery;
c. installations subject to a single authorization in all other cases.

Plants are, therefore, classified according to the installed power and cogeneration capacity, but the innovation in the Legislative Decree concerns the simplification of procedures introduced in an attempt to speed up the authorization procedure.

3.2. Taxation of energy production

An important element for the economic evaluation of the activity in question is the incidence of the tax burden. Art. 1 para. 369 of the 2007 Finance Act (Law no. 296/06) states that «*(…) the production and sale of electric and heating power from renewable agroforestry sources (...) constitute related activities pursuant to Article 2135, third paragraph, of the Italian Civil Code and are considered as producing agricultural income*». In this case, they involve taxation on a cadastral basis of limited importance for the balance sheet of the agro-energy business. The concept of related activity is linked to the principle of prevalence[1], according to which products must derive *primarily* from the main activities or from the use of equipment and/or resources normally used in the business. This taxation on plants has also been maintained in the latest regulatory references for projects that will require authorisation after 31/12/2012.

3.3. Incentives for the production of renewable electricity

Crucial elements among the decisive factors for the activation of a plant are the value and duration of financial incentives for the production of energy produced and sold to the network operator. This paragraph describes the procedures that apply according to the provisions of the Ministerial Decree 6 July 2012: *"Implementation of Art. 24 of the Legislative Decree no. 28 of 3 March, 2011 establishing incentives for the production of electricity by plants using renewable sources other than photovoltaic".*

The new incentive system for the production of electricity from renewable sources, as well as providing a mechanism for gradual reduction of the incentive level[2], is also characterized by the introduction of a maximum annual funding quota (5.8 billion euro per year) and the available power of incentivised energy (figure 3). The Decree provides for two types of incentives:

- a comprehensive incentive tariff (To) for plants with power <1 MW;
- an incentive (I) for plants with power > 1 MW and for those with power not exceeding 1 MW that do not opt for the all-inclusive rate, calculated as the difference between a fixed value (total revenue) and the time zone price of the energy (referring to the zone where the electricity produced by the plant it is fed into the grid).

[1] The principle can be satisfied according to the quantitative requirements (products used in performing related activities obtained from agricultural activity on the farm are prevalent compared to those purchased from third parties) or value (the value of the products obtained from agricultural activity is higher than the cost incurred to purchase third-party products). If neither of the two parameters can be adopted, as in the case of animal slurry, prevalence can be detected by a comparison between the energy deriving from its own products and that derived from products purchased from third parties.

[2] Art. 7 comma 1 (*…) for plants that come into operation in the years after 2013, the value of base incentive tariffs is reduced by 2% per year, with commercial rounding to three decimal places (…).*

Fig. 3 - Basic incentive rates for 2013 and premiums established by the Decree						
BASE INCENTIVE			**ADDITIONAL PREMIUMS**			
Type of diet used	**Power**	**Base incentive rate 2013 for 20 years**	**Cogenerator light performance (Art. 8 para. 8)**	**High performance cogenerator with nitrogen recovery > 60% to produce fertilizers (Art. 16 para. 1 and 2 (*)**	**High performance cogenerator with 30% nitrogen recovery to produce fertilizers (Art. 26 para. 3a (*)**	**Removal of 40% nitrogen, not in cogeneration (Art. 26 para. 3b (*)**
	kW	**euro/kWh**	**euro/kWh**	**euro/kWh**	**euro/kWh**	**euro/kWh**
Products of biological origin	1<P≤300	0.180	0.040	0.030	0.020	0.015
	301<P≤600	0.160	0.040	0.030	0.020	0.015
	600<P≤1,00	0.140	0.040	0.030	–	–
	1,000<P≤5,000	0.104	0.040	0.030	–	–
	P≤5,000	0.091	0.040	0.030	–	–
By-products of biological origin (**)	1<P≤300	0.236	0.010	0.030	0.020	0.015
	301<P≤600	0.206	0.010	0.030	0.020	0.015
	600<P≤1,00	0.178	0.010	0.030	–	–
	1,000<P≤5,000	0.125	0.010	0.030	–	–
	P≤5,000	0.101	0.010	0.030	–	–

(*) Premiums can not be combined with each other.
(**) The by-products of biological origin are shown in detail in Table 1 attached to the Ministerial Decree of 6 July 2012.
Source: our calculations based on Min. Decree July 6, 2012.

As regards the **biomass used,** the classes of incentives indicate a desire to reward projects that use, above all, agri-livestock and agro-industrial by-products as substrates, as well as the organic fraction of waste (in a non-agricultural context), compared to plants designed for the use of "products" (as defined by the regulations) and, therefore, of crops dedicated to energy conversion (specifically, for example, grain silage). In this way, process waste matrices will be better exploited, while it is conceivable that projects related to the exclusive or priority use of dedicated crops will decrease.

As mentioned previously, the other distinguishing feature introduced with the new Decree, is the **"size**" of the system, understood as the installed electrical power. Five classes have been identified to which different tariffs are applied for the electricity produced and provided. The most important classes for the agricultural sector refer to power plants included in the category: 1 ≤ 300 kW, those in the range 300 ≤ 600 kW and thirdly, 600 ≤ 1,000 kW.

The introduction of so-called "bonuses" for cogeneration, for the removal of nitrogen and for the limitation of emissions, as well as achieving desirable targets for energy and environmental efficiency, also contributes to a further selection criterion for plants, based on the profitability that can potentially be obtained by integrating the various processes. This mechanism seems to respond more to business figures who make investments in a framework complementary to local resources and with the need to protect the territory, in reality limiting the spread of initiatives that may, however, be considered as unsustainable (such as high power biogas plants powered exclusively by maize and concentrated in small areas).

The duration of the new incentives, as defined in Annex 1 of the Decree, is extended to 20 years (compared with the 15-year period up to 2012), in order to provide a greater guarantee of stability of profits for the entrepreneur and a longer life time for the plant, so that it will not require final decommissioning after the end of the incentives, but will be allowed to continue operating.

Lastly, the Decree defines three different modes of access to the incentive mechanisms, depending on the power, which for biogas plants (new, fully rebuilt, re-activated, undergoing renovation or upgrading) are:

– **direct access** in the case of plants with power <100 kW
– entry in **Registers** in the case of plants between 100 kW and <5,000 kW;
– **competitive downward auction procedures**, if the power is > 5,000 kW.

4. Assessments of the economic sustainability of biogas production plants

The need for analysis of the cost-effectiveness of an anaerobic digestion plant for the production of biogas at all stages of the supply chain must be stressed: from the production of biomass, to transportation to the construction and operation of the plant, the production and sale of electricity and thermal energy, up to the management and transport of the final digestate.

In addition, new regulatory proposals relating to the value of the incentives as regards the all-inclusive tariff outline the analytical path that will be followed. In particular, the distinction of the rates on the basis of "power" and "diet" requires the valuation model to be set up distinguishing projects by the two categories of biomass that are of most relevance to agricultural enterprises (products or by-products of biological origin) and for two power ranges (from 1 kW to 300 kW, and from 301 kW to 999 kW)., Attention will therefore be focused on the four categories of plant resulting from crossing these two variables.

The goal is to verify how costs are distributed by enterprise and, consequently, to outline a profitability framework applicable to different businesses in the biogas sector, according to new specifications for incentive rates. In order to understand the significance of the results of the calculations, the basic assumptions must be specified, remembering that the indicators will be expressed in euro/kWh of electricity produced and sold:

1) the crop cost of the biomass from dedicated crops is estimated at around €1,750 /ha (based on direct surveys in areas of the Po Valley). To calculate the impact of the cost per unit of electricity produced we adopted the following parameters:
   – average energy yield of biomass: 333 kWh/ton;
   – average yield of maize silage: 55 ton/hectare.

   Therefore, the cost of cultivation of biomass is equal to **0.096 euro/kWh**
2) this cost increases when conditions of business self-sufficiency do not exist; it is then assumed that external land will be obtained through renting to gain some advantages in the operating of the plant: first, to limit external purchase of biomass, which is certainly subject to volatility in grain prices; and second, to meet the minimum requirement for energy production to be classed as a related activity and, therefore, subject to reduced agricultural taxation (self-production of raw material by the business must be above a minimum of 50%);
3) In terms of value, the land rent could, for example, cost €750/ha equal to:
   (750.00 euro/ha /55 t/ha) /333 (kWh/t) = 0.040 (euro/kWh)
   This additional portion of expenditure must be factored into the cost of cultivation, and

therefore for biomass produced on leased land, the total cost becomes **0.136 (euro/kWh)**

4) the transport of biomass entering and digestate leaving the plant is based on assumptions of a maximum distance of 15 kilometres for a maximum quantity of the organic matrix of about 64 t/kW (composed partly of silage and solid phase separated from the digestate). With a unit cost of 3 euro/t, the expense per unit of electricity produced is equal to:
(3.00 euro/t • 64 ton/kW) / (333 kWh/t biomass • 24 t/kW silage) = 0.024 euro/kWh
5) the construction costs of a plant are normally expressed in euro per kW of installed power. The market is currently oriented to values between €3,500 and €4,500 /kW for plants with a capacity up to 1 MW powered primarily by dedicated crops, and € 7/8,000 kW for small plants (~100 kW) powered mostly by manure.
6) the annual cost of operating a plant is mainly composed of: ordinary operating and maintenance costs, annual loan repayments and annual depreciation of capital. As a result, the highest value relates to a 100 kW plant, for which a unit expense of more than €7,000 /kW is assumed and external financing for 80% of the capital invested. For the 999 kW plant, on the other hand, a cost of approximately €4,000 kW is expected.

4.1. Plant management and operating cost

As is well known, the management of an anaerobic digestion plant requires special attention, above all, to ensure continuous operation in order to achieve high annual production of electricity: an indicative objective of 8,000 hours per year may be assumed. Undoubtedly, attaining this result is only viable if the biological, chemical, technical and mechanical aspects that govern the plant are carefully controlled.

It is difficult to indicate a value for average expenditure, although it can be assumed that the unit cost will increase as the power installed decreases, due to the presence of fixed costs that are difficult to eliminate. Therefore, for management expenses we used the same scalar approach as followed for implementation costs: it is estimated that the management of a plant with a capacity of 999 kW would require annual expenditure of approximately €0.030 /kWh of electricity produced, which is equivalent to a total amount of about €243 /kW per unit of power and approximately 243,000 euro in total.

4.2. Costs of finance

The financial costs relate to external financing are proportional to the capital required, the duration of the loan and the rate of interest. For the purposes of calculation, it was assumed that the entrepreneur would rely on an outside agency to obtain financing for 80% of the total investment, with the difference provided by the entrepreneur himself. For the share of external capital, the time assumed for return of capital to the funding entity is 20 years at a rate of 5.0%, while the owner's capital is allocated in a linear fashion during years in which the incentive rate is provided.

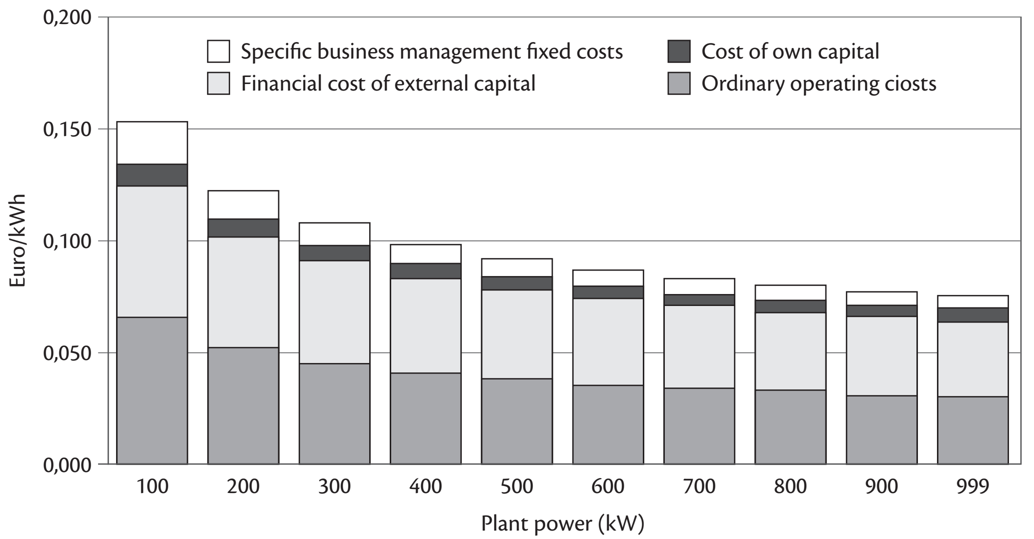
4.3. Common management costs of the agricultural business

It was considered appropriate, for the purposes of evaluation, to allocate part of the administration and management costs of the traditional farm enterprise to the management of the biogas plant. In fact, we assumed the project for the digester to be complementary to the agricultural activity, and a portion of more directly agricultural personnel and operating costs would be addressed to this new productive activity. Specifically, we assumed the need at least for an administrative check of about an hour a day and an amount equal to 1% of the value of the plant for management by the employees of the farm.

At this point we have the necessary values to set up the dynamics of the total management cost of a plant. Based on these assumptions, the total annual management cost for a plant can be estimated to be in a range from a minimum of €0.07-0.08 /kWh (for systems with high capacity) up to €0.15-0.16 /kWh for small installations (figure 4).

The decrease in annual running costs is mainly due to the high initial outlay for the construction of low power plants, which is reflected in an increase in the financial costs related to the issue of the loan. Therefore, the management of small installed power capacities (for example, <100 kW) must be suitably balanced with a supply of biomass at very low cost, such as the use of biological raw material (for example, manure or waste of agricultural origin), and only a very small proportion of silage.

Fig. 4 - Dynamics of the management cost of a biogas production plant with increasing power capacity



5. Risk analysis: comparison between rates of incentive before and after 2012

The rate of incentive for the production of renewable electricity must be compared appropriately with the costs described above. The main objective here is to compare the two situations prevailing before and after 2012, following the radical change in the single incentive rate of 0.28 euro/kWh which ended 31 December 2012 (figure 5). In particular, the following assumptions are made for the evaluation:

a) plants included in the model have increasing power capacity between 100 to 999 kW;
b) the power diet considered consists of the following:
   – biological products: dedicated crops produced on land belonging to the business and external land;
   – biological products: manure from the farm plus a possible maximum proportion of 30% by weight of silage.

c) Cost values for the various scenarios were considered as common: only the value of the rate of incentive and the composition of the diet for powering the plant are modified.

Fig. 5 - Reference scenarios for the analysis

Reference scenarios for a biogas production plant

Duration of payment of tariffs: 20 years — **Power (X)** — **Diet (Y)**

Variables	1<P≤300	300<P≤600	600<P≤1,000
Biological products	0.220 euro/kWh	0.220 euro/kWh	0.180 euro/kWh
Biological by-products	0.246 euro/kWh	0.216 euro/kWh	0.188 euro/kWh

COMPARATIVE ANALYSIS

BEFORE 31 DECEMBER 2012	**AFTER 1 JANUARY 2013**
Power range (100>999 kW) Diet: maize silage produced on and off the farm	Power range (100>999 kW) Diet: maize silage produced on and off the farm
	Power range (100>999 kW) Diet: manure and maize silage produced on and off the farm (up to 30% by weight)

The results we wish to obtain from the simulations have a dual purpose: firstly, concerning the single rate of €0.28 /kWh, to confirm the behaviour of the entrepreneurs in choosing to install mainly high power plants (>999 kW) powered with dedicated crops; and secondly, for the new incentive scheme, to identify strategies that must be followed to achieve a satisfactory level of profitability for the enterprise More detailed clarifications on the results obtained are outlined below (figure 6).

(A) Plants with power range of 100 to 999 kW powered by biological products before 2013

Until 2013, the design of a plant for the production of biogas powered by dedicated crops offered interesting opportunities for entrepreneurs, especially in the case where the entire area necessary to provide silage for the installed power was available on-farm. The growth in profitability was due to two main factors:

– the presence of significant economies of scale that are recorded in the costs for construction and operation of the plant with higher power installed; from 250 kW upwards, the profit became very significant;
– the increase in the cost for supply of biomass, at a rate less than proportional to the decrease in the operating costs of the plant; note that in the model a maximum amount of biomass produced externally on rented land of 49% was assumed.

The results obtained under the "old" incentive scheme led to the construction of a large number of installations with power around the maximum allowed and, only secondly, to consideration of procurement of biomass as an equally crucial factor for success; as mentioned several times, this strategy was risky and, in fact, we have recently begun to see tensions in grain markets and, above all, in land rental, which can cause problems for the total management cost of the plant.

(B) Plants with power range from100 to 999 kW powered by biological products after 1st January, 2013

The second scenario again considers plants powered by maize silage with the same cost characteristics as indicated in the previous case, but with revenues influenced by the incentive rate that began on 1 January, 2013.

The scenario changes dramatically and with a loss of income opportunities for all levels of power installed. Indeed, in this specific case, precisely because of the incentive rate that decreases as the power increases, large plants are the most penalized. The opportunity for profit margins does not exist for any level of power installed. Note, however, that the basic assumptions referred to a portion of leased land: therefore, savings in cost can be achieved if the biomass is completely self-produced, but there is still a high degree of risk for the enterprise.

(C) Plants with power range from 100 to 999 kW powered by biological by-products after 1st January, 2013

The third scenario takes into consideration plants powered by by-products with a maximum use of dedicated crops of less than 30% by weight. It is assumed that the business has available the manure to be used in the process of feeding the digester. In addition, in the case of power of 100 kW, the diet is composed exclusively of the livestock matrix, while as the power increases, an additional proportion of silage up to a maximum of 30% by weight was considered, as permitted by the regulations.

In this case, the theoretical operation proposed shows better operating margins. In fact, the net profit for each level of power installed is always greater than 0.03 euro/kWh, exceeding 0,05 euro/kWh for plants <300 kW.

In absolute terms, it is believed that the most interesting net profit is obtained at two specific points in the growth of the installed power: in fact, around 300 kW the effect of the higher incentive rate becomes relevant for the first stage; at 600 kW, the high power installed and the corresponding electricity produced, can enhance the profit per unit to €0.04 /kWh, although this is lower than for the plants with power up to 300 kW.

For the purpose of the evaluation, it was not deemed appropriate further to increase the size of the plants, because it would be necessary to have farms with herds of a size not commonly found in the Italian plains.

Fig. 6 - Analysis of scenarios										
Before 31 december 2012										
Power (kW)	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**999**
Net base incentive rate	**0,249**	**0,249**	**0,249**	**0,249**	**0,249**	**0,249**	**0,249**	**0,249**	**0,249**	**0,249**
Plant costs	0,154	0,122	0,108	0,099	0,092	0,087	0,083	0,080	0,077	0,075
Biomass Costs	0,098	0,100	0,102	0,104	0,106	0,108	0,110	0,112	0,114	0,116
Transport Costs	0,024	0,024	0,024	0,024	0,024	0,024	0,024	0,024	0,024	0,024
Net income	**-0,026**	**0,003**	**0,016**	**0,023**	**0,027**	**0,030**	**0,032**	**0,033**	**0,034**	**0,035**
After 1 January 2013										
Power (kW) Biological products	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**999**
Net base incentive rate	**0,196**	**0,196**	**0,196**	**0,178**	**0,178**	**0,178**	**0,160**	**0,160**	**0,160**	**0,160**
Plant costs	0,154	0,122	0,108	0,099	0,092	0,087	0,083	0,080	0,077	0,075
Biomass Costs	0,098	0,100	0,102	0,104	0,106	0,108	0,110	0,112	0,114	0,116
Transport Costs	0,024	0,024	0,024	0,024	0,024	0,024	0,024	0,024	0,024	0,024
Net income	**-0,080**	**-0,050**	**-0,038**	**-0,048**	**-0,044**	**-0,041**	**-0,057**	**-0,056**	**-0,055**	**-0,054**
Power (kW) Biological by-products	**100**	**200**	**300**	**400**	**500**	**600**				
Net base incentive rate	**0,219**	**0,219**	**0,219**	**0,192**	**0,192**	**0,192**				
Plant costs	0,154	0,122	0,108	0,099	0,092	0,087				
Biomass Costs	0,000	0,033	0,035	0,037	0,039	0,041				
Transport Costs	0,012	0,012	0,024	0,024	0,024	0,024				
Net income	**0,053**	**0,052**	**0,052**	**0,033**	**0,037**	**0,040**				

In conclusion, it can be argued - albeit with the caution necessary in treating data from theoretical approaches - that in the future, the entrepreneur will have interesting opportunities for plants with different power capacity in the context of scenarios that use biological products. In addition, the operating margin that can be obtained also allows a the possible expensive supply of biomass to be considered when the power installed is to be increased. Conversely, the risks run will be serious if the system is to be powered exclusively with dedicated biomass, especially with cereal silage.

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