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COSTS-BENEFITS ANALYSIS OF A SMALL-SCALE BIOGAS PLANT AND ELECTRIC ENERGY PRODUCTION

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Abstract

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The present work concerns the economic and financial evaluation of a small biogas plant (power plant of 250 kW_{el}), with reference to the case of a biogas plant fed with a bio-matrix classifiable as both a by-product and a product. The study was focused on the comparison of several incentive systems that have followed over time. According to the analysis carried out using some economic indicators, results revealed that the investment profitability was descending passing from the old all-inclusive rate to the current incentive scheme. Furthermore, it is possible to emphasize that the use of products, rather than by-products, penalizes investment by reducing the incentive rate, thus putting the investment in a high financial risk. Thanks to the present study, it can be assumed that the small biogas production plants enable positive benefits in social, economic and environmental terms.

Key words: biogas; costs and benefits; profitability indexes; economic investments

Introduction

The production of electrical energy from the bio energy sector revealed an average increase of 19% a year in Italy in recent years (between 2001 and 2014) from 1 958 to 18 732 GWh (GSE, 2014). In 2014, it accounted for 15.5% of total production from renewable sources. The increase in the energy production from biogas was relevant: it rose from 1,665 GWh in 2009 up to 8,198 GWh in 2014 (GSE, 2014). In this setting, the biggest increase concerned biogas plants using manure derived from animals (Tricase and Lombardi, 2009; Schievano et al., 2009).

The business decision in respect of the construction of an anaerobic digestion plant in a farm almost always involves expensive investments (Piccinini et al., 2008; Agostini et al., 2016; Recchia el al., 2013). Even in smaller firms, significant investment costs cannot be addressed without having a clear framework of their profitability and changes that such technology determines in a productive and managerial identity (Salomon and Lora, 2009; Delzeit and Kellner, 2013). Besides the technical aspects, the entrepreneur should be able to assess the sensitivity of the investment profitability, e.g. Patrizio and Chinese (2016) to changes in active items, such as electricity, price of incentives and incidence of public contributions (Piccinini et al., 2008). In order that a farmer can (Di Giacinto et al., 2012) obtain economic benefits sufficient to repay both his own work and investment, considering the payback time (Holm-Nielsen et al., 2009; Karellas et al., 2010; Carlini et al., 2014), the entrepreneurial choice should be approached with a deep cost-benefit analysis that the introduction of anaerobic digestion technology involves (Piccinini et al., 2008; Uellendahl et al., 2008). The present

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work aimed to examine the evolution of the incentive systems applied to a representative biogas plant of small size (250 kW_{el}) in the Italian context, delving into the question of its economic and financial assessment. The evaluation also took into account the hypothesis of several organic matrices feeding the plant.

The study mainly focused on the comparison of several incentive systems that have followed over time: (i) the *all-inclusive rate* that represent the incentive attached to the 2008 Finance Law and updated according to the Law n. 99 of 23/7/2009; (ii) the Italian Ministerial Decree n. 28 of 6/7/2012 on the power production from renewable energy sources; and (iii) the current Italian Ministerial Decree of 23/6/2016 called "Incentive of power produced from renewable sources different from photovoltaic".

Materials and Methods

The examined plant, considered as a representative case in the Italian context, is based on a farm. The bio-matrix produced, as feedstock for the biogas plant, is classifiable as a biological origin by-product consists of a daily sewage volume coming from pig breeding estimated in 31 tons a day, with the corn contribution of about 9 tons a day.

The contribution of corn in the total bio-matrix input is therefore less than 30%, allowing falling into the type of organic by-products. In addition, since the plant power is less than 300 kW_{el}, the incentive rate is the maximum available: it was of € 0.236/kWh_{el}, as stated in the Tab.1.1 of the Attachment 1 in Italian Ministerial Decree n. 28 of 6/7/2012; while it became of € 0.233/kWh_{el}, as reported in Table 1.1 of Appendix 1 of the Italian Ministerial Decree of 23/6/2016. Regarding the study concerning the use of a bio-matrix classifiable as a product of biological origin, a percentage in corn weight of 37.5% was considered. The use of bio-matrix reduced the value of the incentive rate: it was € 0.180/kWh_{el} regarding the Italian Ministerial Decree n. 28 of 6/7/2012; while it became of € 0.170/kWh_{el} referring to Italian Ministerial Decree of 23/6/2016.

In the case of the old *all-inclusive rate*, the incentive corresponds to € 0.280/kWh_{el} apart from the fact that the bio-matrix is classifiable as a product or by-product. The database for the calculation of the B.M.P. index (Biochemical Methane Potential) was used for the cost-benefit analysis (Koupaieet al., 2014; Esposito et al., 2012).

In the study context, from the economic point of view, it is hypothesized the use of financial indebtedness for 100% of the investment. The characteristics of a representative plant with particular reference to the engine to energy electric production are reported in Table 1. The specific costs derived from the subsidized plant monitoring activity are summarized in Table 2.

Table 2
Specific costs

Parameter	Unit of measurement	Value
Service cost (including maintenance)	[€/kWh]	0.025
Anaerobic Digestion Plant specific cost	[€/m^3]	200
Cogenerator specific cost	[€/kWel]	1.500
Additional storage tank	[€/m^3]	50
Biomass storage silos	[€/t]	50
Silage	[€/t]	40

Table 1
Characteristics of a representative plant

Parameter	Unit of measurement	All-inclusive rate	Italian Ministerial Decree n. 28/2012	Italian Ministerial Decree June 23th, 2016
Plant functioning	[day/ year]	365	365	365
Process temperature	[°C]	35	35	35
Low Heat Value CH_4	[kWh/Nm^3]	9.88	9.88	9.88
Methane percentage	[%]	60	60	60
Cogenerator working hours	[h/year]	8200	8200	8200
Cogenerator total power	[kW]	713	713	713
Electrical performance	[%]	35%	35%	35%
Thermal performance	[%]	40%	40%	40%
Cogenerator electrical power	[kW]	250	250	250
Gross electrical energy produced	[kWhel]	2 050 000	2 050 000	2 050 000
Gross thermal energy produced	[kWh]	3 807 143	3 807 143	3 807 143
Self-use electric energy (EE)	[%]	7	11	11
Net electrical energy produced	[kWhel]	1 906 500	1 824 500	1 824 500

The estimation carried out for the construction of a small biogas plant of 250 kW_{el}, fed with the considered matrix, identified the main costs for its construction and maintenance (Table 3 and 4).

Table 3
The estimated investment for the construction of the biogas plant considered in the study

Device	Cost [€]
Anaerobic Digestion Plant	429 821
Cogenerator	375 000
Tank for Silage	182 500
Grid connection of medium voltage	60 000
Planning and Safety Costs	37 000
Various Costs	80 000
TOTAL	1 164 321

Table 4
Management and plant maintenance costs

Resource	By-product case [€/year]	Product case [€/year]
Full Service (maintenance included)	51 250	51 250
Organic matrices	146 000	160 600
Insurance policy	3 000	3 000
Biology monitoring	15 000	15 000
Digestate scattering	5 000	5 000
TOTAL	220 250	234 850

Results and Discussion

Results of the financial analysis of the investment, processed using the discounted cash flow method, are reported in Table 5. In the specific case related to the use of by-products and products such bio-matrices in input to the plant has been studied with respect to three kinds of incentive systems or the all-inclusive rate, to Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree of 23/6/2016.

Cost-benefit Analysis (all-inclusive rate)

Economic and financial characteristics of the investment are illustrated when the plant is subsidized under the old all-inclusive rate. Above all, the NPV index (net present value) represents the difference between the sum of all the discounted cash flow (gross operating margins of 15 years discounted at year 0), and the investment appears positive and equal to € 1 881 148 (Figure 1). This result means that the investment is economically and financially profitable as it creates value.

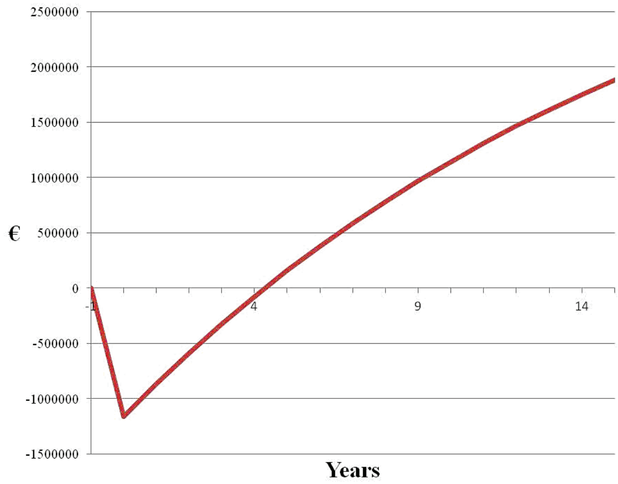

Fig. 1. NPV tendency - All-inclusive rate
(*Source*: our elaboration on data)

Another alternative method of investment valuing closely related to NPV is IRR (Internal Rate of Return) that is used to evaluate the attractiveness of a project or investment. It represents the interest rate at which the NPV of all the cash flows (both positive and negative) from a project or investment is equal zero. The investment project is desirable because the IRR, the value of which is equal to 26.1%, is higher than the capital opportunity cost, assumed 6% for comparable risk projects. It is characterized by a Pay-back Time (PBT) of less than 4 years (Table 5).

Cost-benefit Analysis (Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree on June 23^th^, 2016)

The same system seen before has also been studied in relation to the incentive system associated with the proposed tariffs in Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree on June 23^{th}, 2016, where by-products and products are used as inputs (such as bio-matrices) (Figure 2).

Since the plant remains the same, both the investment and management costs are unchanged. However, the amount of the incentive rate appears different: in the case of use of by-products, it is equal to € 236/MWh_{el} according to Italian Ministerial Decree n. 28/2012, and € 233/MWh_{el} according to Italian Ministerial Decree on June 23^{th}, 2016. If the bio-matrix is classified as product, the incentive would be reduced to € 180/MWh_{el} and € 170/MWh_{el}. When calculating the profitability of the plant using the aforementioned two decrees, it is crucial to think about, with respect to the old all-inclusive rate, an incentive time horizon that increase from 15 to 20 years, in

Table 5
Economic analysis

Parameter	All-inclusive rate[1]	Italian Ministerial Decree n. 28/2012	
		by-product	product
Incentive duration*	15	20	20
Rate **	0.28	0.236	0.180
Sale Earning EE ***	533 820	430 582	328 410
Investment ****	1 164 321	1 164 321	1 164 321
Gross operative margin ***	313 570	210 332	108 160
Pay Back Time*	3.7	5.5	10.8
Share capital ***	77 621	58 216	58 216
Net operative margin ***	235 948	152 115	49 943
Passive interests ***	42 260	43 294	43 294
Total interests ****	633 904	865 895	865 895
Initial Finance ****	1 798 226	2 030 216	2 030 216
Net income ***	193 688	108 821	6 649
Interest rate [%]	6.00%	6.00%	6.00%
NPV ****	1 881 148	1 248 170	76 265
IRR [%]	26.1%	17.3%	6.8%
Parameter	All-inclusive rate[2]	Italian Ministerial Decree (June 2016)	
		by-product	product
Incentive duration*	15	20	20
Rate **	0.28	0.233	0.170
Sale Earning EE ***	533 820	425 109	310 165
Investment ****	1 164 321	1 164 321	1 164 321
Gross operative margin ***	313 570	204 859	75 315
Pay Back Time*	3.7	5.7	15.5
Share capital ***	77 621	58 216	58 216
Net operative margin ***	235 948	146 642	17 098
Passive interests ***	42 260	43 294	43 294
Total interests ****	633 904	865 895	865 895
Initial Finance ****	1 798 226	2 030 216	2 030 216
Net income ***	193 688	103 347	-26 195
Interest rate [%]	6.00%	6.00%	6.00%
NPV ****	1 881 148	1 185 389	300 464
IRR [%]	26.1%	16.8%	2.6%

[1] It should be noted that according to the incentive system based on all-inclusive rate there is no distinction of bio-matrix in product or by-product
[2] It should be noted that according to the incentive system based on all-inclusive rate there is no distinction of bio-matrix in product or by-product
* in years,** in € / kWh, *** in € / year, **** in €

addition to a self-consumption of less than 11%. Any difference would be counted and paid by the Italian Manager of Energy Services (GSE) at the market price, which is about € 100/MWh$_{el}$. Though, such aspect was not taken into account in the present work. Similarly, the H.E.C. bonus (High-efficiency cogeneration) was not considered, as nitrogen bonus and other expected rewards: their valuation is difficult to estimate and therefore they do not correspond to a definite income. It should be emphasized that the non-consideration of the above bonuses and rewards is adopted by all the plant companies which build plants in drafting the investment business plan.

From the analysis above, results proved how the values of NPV, IRR and PBT (Profit Before Tax) highlight that an investment of this type appears to be financially risky. This statement is mainly due to the fact that the incentive value drastically is reduced from € 280/ MWh$_{el}$ of the all-inclusive rate to 180 €/MWh$_{el}$ of Italian Ministerial Decree n. 28/2012 and 170 €/MWh$_{el}$ in the case of Italian Ministerial Decree on June 23th, 2016. Furthermore, the rising costs of bio-matrix,

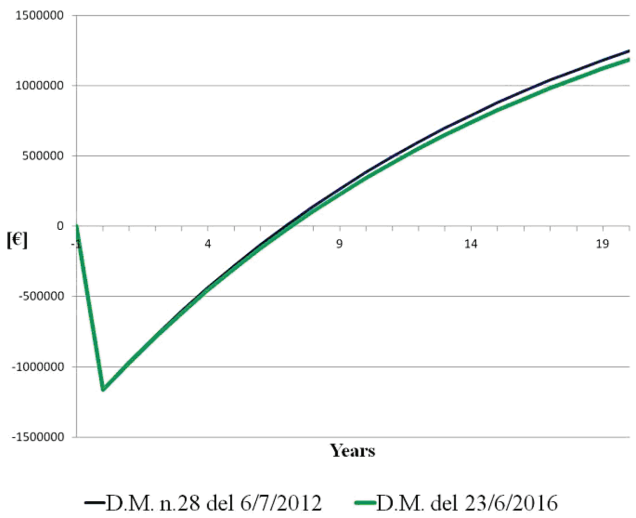

Fig. 2. NPV tendency – proposed fares in the Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree on June 23th, 2016 in the case of by-product use and of product use (*Source*: our elaboration on data)

due to the increase led by the amount present in the composition of the same bio-matrix, should be considered.

Conclusions

Alternative energy sources are becoming ever more a global reality: their use allow both to meet the growing demand for energy and to reduce the environmental impact (Monarca et al., 2011).

From the economic and financial analysis and the comparative study, results revealed how the biogas plants from 250 kW_{el} are still an attractive investment (Karellas et al., 2010), despite the obvious reduction the incentive base rate has suffered over the years (Agostini et al., 2016). From how the current incentive legislation is structured, small plants (with a power less than 300 kW_{el}) have the best incentive rate. Particularly, these plants are convenient only if the biomass used is: (i) classifiable as a "by-product of biological origin"; or if (ii) it is constituted for at least 70% in weight by by-products, which normally represents a zero-cost biomass.

Livestock production involves a significant environmental damage (Mathias, 2014). A additional advantage in the biogas production derives from the fact that it avoids environmental problems, also due to the spreading of manure directly in soil and other issues concerning the sewage disposal (Tricase and Lombardi, 2009; Hoppe et al., 2016). In this background, a biogas plant provides (i) an economic return in relation to the sale of produced EE (Electric energy) and at the same time (ii) avoids the trouble of disposing of the slurry and their related costs. Besides, the digestate (a by-product of the anaerobic digestion process) can be used as fertilizer for the major agricultural crops, in full or partial replacement of chemical fertilizers on the market, thereby reducing the farming management costs.

Thanks to the present study, it can be assumed that the small biogas production plants enable positive benefits in social, economic and environmental terms. Actually, small plants fed with by-products or agro-industrial waste allows: (i) the recovery and the reuse of production waste; (ii) the possible enhancement of a short chain; and (iii) a sustainable development, as well at the local scale (e.g. Bond and Templeton, 2011).

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