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Assessment of optimal size of anaerobic co-digestion plants: An application to cattle farms in the province of Bari (Italy)

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ABSTRACT

Energy production from anaerobic digestion of organic waste and dedicated digestable biomass is a promising climate change mitigation option. Over the last ten years anaerobic digestion has become established in many European countries. The plants have been developed for renewable energy generation, but also to control the emission of odors from zootechnical farms and to stabilize biomass before its agronomic use. In Italy the subsidies available for power generation from biomass have given rise to renewed interest in biogas, creating new opportunities for the agricultural and livestock sectors.

Despite of this, in Southern Italy the manure is highly dispersed over a large number of small-size cattle farms, while power generation facilities are affected by scale economies and the aggregation of input biomass is a major logistic, managing, economic and environmental drawback towards the diffusion of such technologies. In this paper, an investment decision methodology for the assessment of optimal size and feedstock mix of biogas power plants fed by cattle manure and energy crops is presented. The methodology is applied to one of the most promising basins of Puglia region, in Southern Italy, represented by the Municipalities of the Local Action Group "*Terra dei Trulli e del Barsento*", Province of Bari. The main factors influencing the profitability of these investments are assessed, with biogas power plant size ranging between 50 kW and 1 MW, and on the basis of the recently introduced feed-in tariff scheme for such plants (D.M. 6 July 2012). The results show that a high manure recovery rate, the reuse of biogas slurry and the cogeneration options are major key factor for the profitability of the investments.

Contents

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1. Introduction

Anaerobic digestion (AD) is a very promising solution for the treatment of agricultural and zootechnical wastes, preventing pollution and leading to efficient energy production. In Europe, enhanced production of biogas from animal manure and other fermentable biomasses is encouraged by the European Directive for promotion of renewable energy sources [1] with mandatory implementation through National Action Plants at Member States level.

The manure produced by cattle farms might be used to produce biogas by AD processes, to be directly converted into heat and power by internal combustion engines or upgraded to biomethane and fed into the gas network. The subsidies available in Italy for biofuels (green certificates and/or feed in tariff for renewable electricity, feed in tariff for biomethane) [2,3], in agreement with EC Directives [1] are increasing the interest in the energy conversion of such animal wastes, also in combination with other residual and dedicated fermentable biomasses. Moreover, the recovery of animal manure for energy generation could facilitate the control of odor emissions and stabilize the biomass before its agronomic use. In Italy, about 500 AD biogas plants fed by manure, energy crops and/or agricultural digestable substrates are installed by 2011. The prevalent size of the plant increased from 150 to 200 kWe of 2009 to about 500 kWe of 2010, with a total installed power of about 388 MWe at end 2011.

The Province of Bari (Puglia Region, Italy) includes many cattle farms and high density of cow breeding. About 70% of these farms is located in the seven Municipalities included in the Local Action Group (LAG) "*Terra dei Trulli e del Barsento*", in the South of the Province of Bari. Despite of the high incentives available for biogas generation, the manure in Southern Italy is highly dispersed over a large number of small-size farms, so increasing the biomass transport costs. Moreover, the aggregation of several farms to feed a centralized plant presents several supply side managing issues, since the optimal operation and the consequent bankability of these projects requires reliable biomass supply chains as regards quality, quantity and delivery price. On the counterpart, biogas facilities are affected by scale economies and their global efficiency is influenced by the plant size, so that a minimum quantity of biomass feedstock should be available for a profitability of the investment. One possibility to overcome these barriers is to enlarge the biomass supply chain by co-digestion of other residual digestable biomasses (such as diary, brewery, winery, olive and other agro-industrial wastes, or organic fraction of urban wastes) but also of dedicated energy crops. In the first case, the low or even negative waste biomass supply cost makes profitable the investment, but the permitting issues can be quite complex and the final agronomic use of biogas slurry is more difficult for technical and permitting issues. In the second case, the land suitability for energy crops, the, sustainability implications of water, fertilizers consumption and whole chain energy balances, the food/animal feed vs. energy dynamics and the economics of the investment (biomass supply costs) are the main drawbacks. For these reasons, the selection of the optimal biogas plant size for a given territory and mix of feedstocks can be a complex issues, influenced by economic, technical, logistic and organizational factors. Another major barrier towards the development of biogas routes is the scarcity of reliable information for decision-makers and investors about the biomass energy potentials. In fact, except for very general data and statistics values, there is poor information about the quantity of manure and other agro-industrial by-products that could be converted into energy in a sustainable way.

In this paper, a general framework for the techno-economic assessment of biogas production from cattle manure and energy crops is proposed and applied to the case study of the seven Municipalities of the LAG Terra dei Trulli e del Barsento, in the Puglia Region. In the first part, the general approach for the selection of the optimal biogas plant is presented. In the second part, the approach is applied to the territory of investigation. In particular, the assessment of both cattle manure and dedicated energy crops potentials for biogas generation is described, by means of structured interviews with local farmers and main operators of the sector. Moreover, the profitability assessment of biogas CHP plants fed by manure and energy crops is proposed. The scenarios of only electricity generation, cogeneration of heat and power and sale of biogas slurry as fertilizer for agronomic use are considered, and the power size ranges between 50 kW and 1 MW. The aim of the research is to evaluate the optimal biogas plant size under various scenarios for the territory under study, and assess the influence of scale economies, scale vs. efficiency dynamics, supply chain costs, collection radius size and incentive levels on the optimal biogas plant size selection.

2. Optimization of biogas power plants size

Biogas power plants can be conducted at a wide range of capacities. The problem of optimal size calculation of biomass-to-energy conversion plants has been widely addressed in literature, on the basis of the trade-off between the high conversion efficiencies and economies of scale of large size plants and the low biomass collection radius, transport costs and feedstocks collection and management requirements of small size plants [4–8].

Factors such as feedstock availability and spatial distribution, terrain and road conditions, biomass transport specific costs, storage costs, existing energy infrastructures, biomass seasonality issues, conversion plant scale factors and efficiencies influence this optimization problem. Logistic aspects are particularly relevant when low energy density and highly dispersed feedstocks are used, such as in the case of cattle manure. Moreover, small