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The case study of an innovative small scale biomass waste gasification heat and power plant contextualized in a farm

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Abstract

The use of biomass waste in high efficient low pollutants emissions micro-cogeneration plants overpasses the main biomass barriers: competition with the food and material uses, dispersion of a low energy density fuel and high emissions. Evaluations of present technical aspects, economic benefits and their future projections are very important to bring into focus the needs of the technological development of this energy application.

This paper is focused on a small (250 kWth) steam gasification fluidized bed and hot gas conditioning system, contextualized in the case study of a farm situated near Rome. Since most of usable biomass waste comes from agriculture, appraisal of applicability to real rural contexts deserves closer examination, considering the necessity of a small size solution as well. A feasibility study of an actual employment of this energy system has included: biomass availability and energy consumption analysis, biomass and gasification tests, power plant sizing, using experimental data and chemcad simulation. Finally an economic analysis has been carried out by varying the main economic parameters. Olive pruning are confirmed as very suitable, and in this case, able to satisfy the farm energy consumption. Global electrical efficiency of 25% can be achieved without any auxiliary fuel consumption. Consumption of 60% of the heat generated are required, meanwhile investment and biomass costs up to 8000 €/kW and 100 €/t can be sustained, especially if the farm electricity cost are higher than 0.15 €/kWh.

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Keywords: biomass, gasification, hot gas conditioning, power plant, economic analysis

1. Introduction

Recently, a shift in the biomass energy uses is occurring,from traditional (e.g. combustion to produce heat[1]) to modern's one (e.g. processes to produce electricity and bio-fuels integrated in farms and

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industries[2,3]) [4]. Distributed generation emerged as a different approach to traditional power generation, aiming to reduce distribution losses and favour the use of renewable energy resources locally available such as biomass [4,5], solar [4,6], wind, etc..Biomass technical and economic potentials are higher than actual world energy consumption[4,7]. Nevertheless, competition with the food and material demand, dispersion of a low energy density fuel and high emissions limit the bioenergy use (e.g. the Italian territory amounted to about 30 million metric tons/year [8]). Furthermore, at small scale, the technology development issues still remain. Actually, a small biomass power plant can reach annual operating hours lower than 6000, efficiency lower than 25%, high local and environmental meaningful impacts [2]. Therefore, technical and economic aspects of high efficient low pollutant emissions micro-cogeneration plants applied in agricultural farm have to be analysed in order to overcome the main biomass barriers. Gasification-ICE based cogeneration of lignocellulosic residues/waste, as the one of the present case, is the most direct and accessible way to power generation[9–13]. After the biomass waste analysis and the relative gasification tests, starting from the farm energy consumption, a power plant has been sized and the efficiencies calculated, using experimental data and chemcad simulation. Finally an economic analysis has been carried out, by varying the main economic parameters.

2. Description of the farm studied and the activity

The case study is an olive/house farm ("Il Bagolaro") located in the area so-called *Sabina*, north of Rome that consists of 150 olive-growing hectares (14080 trees);0.64 viticulture hectares (2000 trees);2 wooded and pasture hectares;0.13 fit for seed hectares.

Pruning and olive residues total 330 tonnes per year plus 66 tonnes of leaves. Pruning residues from viticulture amount to 2 tonnes per year and, from wood, 6 tonnes. The residues from seed hectares total 1 ton per year. These values have been assessed and determined considering mean values of residual products of the last five years. The farm is already equipped with a chipper to process the biomass to a uniform size necessary to feed a biomass boiler which can be used for the gasifier. Owing to the fact that the biomass analysis is a very important step [14],the residues have been sampled and analysed and in the following paragraph the results of the most important of them are shown.

3. Biomass analysis and gasification tests

The gasification test rig is shown in Figure 1.

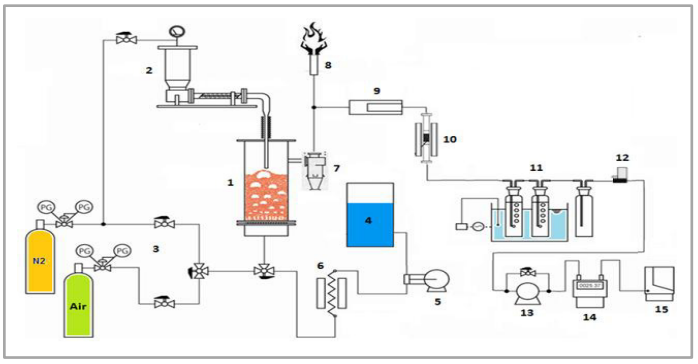

Fig. 1.Test rig: (1) bubbling fluidized bed gasifier; (2) biomass feed system; (3) agents inlet; (4) water storage; (5) pump; (6) electric steam generator; (7) cyclone; (8) torch; (9) ceramic candle filter; (10) secondary reactor; (11) TAR condensation system; (12) mass flow controller (13) vacuum pump; (14) cumulative gas flow meter; (15) gas-chromatograph (TCD).