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Biomass residues revaluation with energy production in a nursery company

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ABSTRACT

In the Tuscany region, Italy, nurseries produce a large amount of biomass residual and treat it as waste product from working activity, usually. The aim of this study is to evaluate a different way to use residuals for the nursery company *Vannucci Piante* (Pistoia), from the availability of residuals to the thermal demand of the company. The possibility of internally treating the biomass in order to transform it into solid fuel has also been taken into account. The thermal demand derives from the heating of greenhouses and offices during the winter period. The thermal energy requirement and the solid biomass fuel availability are studied in order to be conciliated. Three different solutions have been evaluated, considering co-generation and incentive bonus for the production of thermal and electric energy, as provided by the Italian law. The feasibility of the solutions has been analysed and the results have been compared, in order to describe the best solution in economic terms. As emerged in this study, policies for renewable energy in Italy are not up to the task of supporting those type of investment, in particular for agricultural waste revaluation.

1. Introduction

The nursery sector in Europe involves 90,000 ha of cultivated land and 120,000 ha for nurseries. Production reached 19.8 billion Euros in 2011, mainly concentrated in the Netherlands (33%), Italy (13%), France (12%), Germany (12%) and Spain (11%). As for Italy, up to 13,000 ha concern potted flowers and plants. Despite the large area taken by nurseries and the sector's economic relevance, most Italian companies are characterized by their limited size: 64% of nurseries have less than 1 ha of extension (Sarri et al., 2013).

Agricultural greenhouses areas have greatly risen worldwide over the last few decades. A large amount of energy input is required, in order to maintain an appropriate temperature for crop growth during the winter and summer seasons. Energy demand prediction needs to enhance energy management and energy savings of the agricultural greenhouses.

The demand for energy in agriculture has increased considerably with the introduction of high-yielding varieties and mechanized crop-production practices. Therefore, it is necessary to implement a switch from conventional to alternative energy sources. Generally, studies have been concentrated on worldwide production of field crops such as wheat, rice, soybean, cotton, maize, mustard, cluster bean, green gram, pearl millet, sugarcane, etc. in order to improve the energy output–input analyses and to investigate their relationships (Unmole et al., 1987; Satpathy et al., 1991; Singh et al., 1999; Singh et al., 2000; Saha et al., 2002). At the same time, agricultural companies' residuals are mainly composed by biomass, and smaller percentages by plastic, paper and iron.

Even if Italian nurseries' area is only 1.2% of the utilized agriculture area (ISTAT, 2013(istituto nazionale di statistica), 2013), nurseries represent the most considerable working activity for some Italian districts.

Over the last few years, several machine manufacturers have been offering dedicated implements for collecting pruning residue. These machines generally derive from conventional mulchers, equipped with a storage bin or with a blower, the latter designed to direct the flow of comminuted residues to a conveyor belt (Daou et al., 2009). In order to separate biomass from soil part, many authors propose to use innovative shaker machine for optimizing the process (Boncinelli et al., 2015).

The input energy (and its cost) of a farm is studied in many paper. Mohammadi and Omid (2010) determined the energy use efficiency for the production of cucumber and compared input energy use with input costs in the Tehran province, Iran. They

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Nomenclature

C_i	Thermal energy valorisation coefficient (from italian law "Conto termico") [€/kWh]
C_e	Emission valorisation coefficient (from italian law "Conto termico") [−]
E	Annual energy [MJ/y]
$flow_{bio}$	Flow rate of drum machine
i	Interest rate [−]
Ia	Annual incentive for biomass boiler (from italian law "Conto termico")
Mo	Moisture on dry basis [%]
M	Mass [kg]
M_{bio}	Quantity of green residues processed;
LHV	Lower heating values [MJ/kg − MJ/Sm^3]
n	Year of investment [y]
NPV_n	Net present value at year n [€]
P_n	Nominal thermal power (from italian law "Conto termico") [kW]
Pow_{drum}	Mechanical power supply by drum machine
PI	Profitability index [−]
PBP	Pay back period [y]
Q	Thermal power [kW]
r	Latent heat of vaporization [MJ/kg]
S_0	Initial costs [€]
S_{diesel}	Cost of diesel used by drum machine
S_k	Annual cash flow [€]
t	Time of estimated annual work of boilers [h] (from italian law "Conto termico")
t_{work}	Time of working machine to process a certain quantity of biomass [h]

Greek symbols

η	Efficiency

Subscripts

bio	Biomass
d	Diesel fuel
dry	Dry
ng	Natural gas
w	Water
wet	Wet

Acronyms

LHV	Lower Heating Values
NPV	Net Present Value
ORC	Organic Rankine Cycle
PBP	Pay Back Period
PI	Profitability Index

also introduced a mathematical model based on greenhouse farms. Hamedani et al. (2011) examined the energy use patterns and the relationship between energy input and yield for grape production in Malayer region of Hamadan Province, Iran. Other researchers Rafiee et al., (2013) examined energy use patterns and the relationship between energy inputs and yield for prune production in the Tehran province of Iran and they presented a comprehensive picture of the current status of energy consumption and some energy indices.

Other studies focused on energy consumption of greenhouses. (B. Ozkan C. F., 2007) examined the energy use patterns and cost of production in a greenhouse and open-field grape production. Canakci and Akinci (2006) investigated the energy use patterns in greenhouse vegetable production, in order to determine the energy output–input ratio and their relationships. Kuswardhani et al. (2013) estimated energy consumption per unit floor area of greenhouse and open field for tomato, chili and lettuce production in Indonesia. A model-optimized prediction (MOP) methodology is proposed (Yang et al., 2016), in order to predict the energy demand of greenhouses with a better performance of accuracy and cost. (B. Ozkan A. K., 2004) examined the energy equivalents of inputs and output in greenhouse vegetable production in the Antalya province, Turkey, for the production of four greenhouse crops (tomato, cucumber, eggplant and pepper).

Many other researchers studied the use of pruning. Pruning can be treated in order to recover major quantities of organic materials, in particular wood-chip and substrate. Wood-chip can be used as a bio-filter or as a bio-fuel depending on the efficiency of separation and the quality in terms of type, heat value, moisture and size. Substrate can be reintroduced in field, in order to maintain ground level or mix it with virgin substrate (Sarri et al., 2013). Some researchers studied pruning harvesters (Picchi and Spinelli, 2010; Croce et al., 2013) or production of compost and biogas from green residues (Chilosi et al., 2015; Baldi et al., 2016). Other researchers proposed a prune recycling. In fact, (Z. González, A. Rosal, A. Requejo, A. Rodríguez, 2011) characterized chemically orange tree pruning and use it in pulping and combustion processes. Moreover, they proposed it as a suitable cheap energy source by combustion. Energetic and economic analysis of a tri-generation system fueled only with tree pruning residues are proposed (Dentice d'Accadia et al., 2016; Clodoveo et al., 2016).

Pistoia (43°54′N, 10°41′E. 30 a.s.l.), is a city located in the Tuscany region, in the center-north of Italy, and it has the greatest plant nursery district in the country. This area is characterized by an average rainfall of 1300 mm per year, average winter temperature around 5/7 °C with minimum peaks of −10 °C and summer temperature around 21/23 °C with maximum peaks of 40 °C. The soil consists of alluvial deposits which are fertile and rich in sand and silt. The above-mentioned conditions are ideal for cultivating outdoor ornamental plants. This is the reason why Pistoia has become the most important nursery district in Italy and a major one in Europe all over the years (Lucchetti et al., 2016).

Currently, this district has about 4100 ha of field-grown plants, 1000 ha of pot-grown plants, and about 100 ha for greenhouse cultivations. The companies operating in this sector are more than 1500, with 5500 workers. Half of them are employees, while the others are entrepreneurs and independent small farmers. The estimated gross saleable production is around 500 million euros, with 300 million euros of export. Pistoia's nursery production represents about 25% of the national production and more than half of it is exported (Lucchetti et al., 2016).

Green residues in the Pistoia district are generally treated like wastes by nurseries, even if the Italian law could acknowledge this type of residues as a by-product of nursery activity.

Reusing biomass as energy supply for the nursery can reduce CO_2 emission, but is it an economically competitive alternative to fossil fuel?

The aim of the present study is to analyze the benefits of different treatments of biomass, in terms of waste recycling, revaluation of biomass waste and energy saving, as well as the possibility to use different energy sources. Thermal and electric energies can be produced starting from the wood-chip source: their quantities are evaluated in order to cover the energy needs of the company. Biomass production system and energy generation plants are determined in terms of technical data and economic costs.

This study is referred to *Vannucci Piante*, one of the largest nurseries located in Pistoia. Even if the study is referred to a single company, the proposed solutions can be applied also to other nurs-