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Biomass supply to a coal power plant under sustainable development conditions

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Abstract. Nowadays, biomass residues of wood forests have no specific application in many areas of the world. Wood forest can be a bioenergy supplier to substitute the use of fossil fuel. The forest area owns residues when the cleaning is not carried out in a periodic way, mainly because the management of residue is very complicated as a consequence of the orography.

This work aims to improve existing methods and develop new ones for evaluation and utilization of forest wood residue from cleaning and thinning in accordance with the safety and environmental requirements of the biomass feedstock in a coal power plant for a sustainable industry. This implies an analysis of both the resources and the existing limitations for a proper valuation considering technical and environmental restrictions.

The potential forest residues existing in the studied area can contribute to reduce the fossil fuel dependence. The potential feedstock for the coal power plant is 90 dry kt/year, which is equivalent to 24 MW_e and generates 165 kt/year of CO_2 neutral emissions.

Key words

Bioenergy, feedstock, forest, power plant, wood residue.

1. Introduction

Environmental sustainability represents one of the major strategic objectives in the world. One of the ways to reduce greenhouse gases (GHGs) emissions is switching from fossil fuels to biomass in the energy supply sector [1].

The EU governments are developing and implementing renewable energy policies where biomass is one of the most important energy sources. Producing nearly CO_2 free electricity is one of the most important aims that should be achieved [2]. This could be attained by means of using biomass as fuel, a renewable energy normally evaluated as CO_2 neutral in energy production [3].

Biomass is defined as the non-fossilized organic matter formed in a biological process. This can be transformed by diverse physical or chemical processes into solid, liquid or gaseous fuel and it can be used as a bioenergy source.

An interesting and promising alternative for the production of electricity from biomass is through its co-firing in coal power plants already in operation [4]. Co-firing means reducing CO_2 and SO_2 emissions and it may also reduce NO_x emissions [5].

Bioenergy from forests needs to be studied under a sustainable point of view of bioenergy effect in the future, due to policies based on sustainable development in the world. In some countries, disposal of wood residues, can pose a problem. Yet they have significant potential to be used economically and ecologically in the production of energy. In Europe, there are great difficulties to produce biomass assessments due to the lack of geo-referenced databases of forests and made with standardized procedures [6]. It is expected that this applied bioenergy study will help to fill that gap and it will be useful for energy suppliers.

The aim of this work is to evaluate the available biomass and bioenergy and the management implications under sustainable development conditions to maximize the biomass feedstock for cofiring in a coal power plant.

2. Materials and methods

The coal power plant has 50 MW_e and makes use of "the Circulating Atmospheric Fluidised Bed Combustion (CAFBC)" technology. It is located in the Asturias region, in the North of Spain. The boiler is totally based on coal as fuel.

Coal and biomass fuels are different in composition. The objective of this work is to define the availability of the indigenous biomass feedstock. The potential biomass feedstock for biomass cofiring is based on residues of the forest resources surrounding the plant.

The theoretical cofiring technology could be based on independent fuel preparation and feeding lines. These feeding lines supply the coal boiler with biomass. Coal cofiring was successful with up to a 20% biomass mix.

Some works are devoted to the description of Geographic information systems (GIS) methods to determine the biomass availability. These allow the association of the available energy obtained for each of the corresponding boundary map [7], [8].

For the evaluation of forest biomass resources the BIORAISE GIS software from the Centre of Energy Research, Environment and Technology (CIEMAT) has been used taking into account the total and the available biomass resources, as well as energy and costs in the study area [9].

The evaluated residues are from specie categories (conifers, broadleaves and mixtures of conifers and broadleaves). Hereinafter the latter ones will be referred to as mixtures. The conifers include pine trees, whereas the broadleaves include beeches, eucalyptuses, oaks and chestnuts. Wood residues consist of branches and tops (including leaves) obtained from cleaning, thinning and felling operations [10].

The wood residues generated as a consequence of the forest cleaning activities are mainly brushwood, heaths and plant debris. An example of these activities is the thinning that is carried out previous to any reforestation. It consists in eliminating the heath of a surface by a mashing action using the appropriate machinery. For the cleaning of the forest masses, disbranching is carried out to eliminate a part of the tree-lined one to achieve an optimum density for improving the final production. In this case the residue would be constituted by the eliminated trees. The main problem of this type of residue is its dispersion and difficult accessibility**.**

For the calculation of the resource, the area of a circle with origin at the coal power plant and a 55 km radius have been considered [11], [12]. This limits how much biomass supply would actually be available to a plant.

Fig. 1 represents the collection point and the collection area.

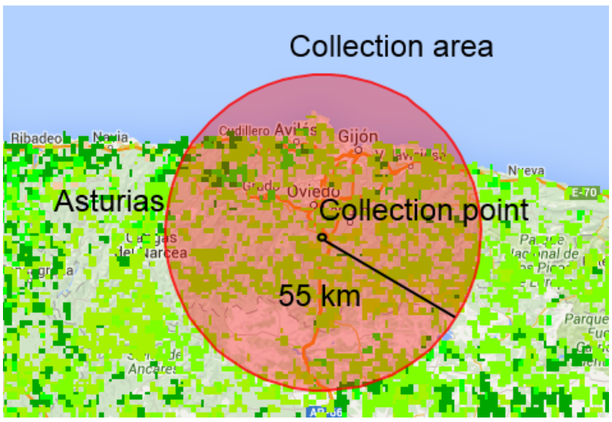

Fig. 1. Collection point and collection area. Adapted from [9].

The collection point will be located at the coal power plant.

The available biomass (m), that is to say, the biomass suitable to be energetically exploited, is obtained from total biomass by techno-economical and environmental factors [10].

Techno-economical constrains derive from ground conditions to access to raw material and environmental constraints come from ground nature [9].

The environmental restrictions that have been adopted for all forests, including protected areas, have been the following:

1) *slope.*
2) *erosion risk.*
3) *organic carbon content in top soil.*

The biomass (m) is evaluated on dry mass basis (dry t).

The energy from the available residue (E) is the result of multiplying the mass from the Lower Heating Value (LHV) and is obtained from (1).

$$E = m \cdot LHV \qquad (1)$$

The average energy content, measured in Lower Heating Value (LHV) from the moisture free residue has been evaluated at about 17.7, 19.0 and 18.3 GJ/dry t in broadleaves, conifers and mixtures, respectively [10].

The basic costs have been calculated for Spanish conditions. The evaluated costs include collection, baling and short transportation from stand to collection point. These parameters are defined by analysis model of the BIORAISE GIS.

The total cost (TC) of the available residue is the sum of the average collection (Cc) and transportation (Ct) cost [13], as in (2).

$$TC = Cc + Ct \qquad (2)$$

In the study of the different operations of production of residual forest biomass (cleaning, thinning and felling) factors of influence such as the costs involved and the land slope must be taken into consideration [9].

The average transportation cost (Ct) is the cost per dry t of the available residue transported to the collection point.

Transportation cost includes driver, vehicle and fuel; for the latter, a diesel average price of 1.45 EUR/l is assumed

3. Results

Table I shows the total and available masses of the forest biomass in the collection area. They have been estimated for the operations of harvesting and short distance transportation by BIORAISE GIS analysis model.

Table I. – Biomass resources.

Type	Available Mass (m) (dry t/year)	Total Mass (M) (dry t/year)
Broadleaves	81,026.35	180,424.98
Conifers	2,793.35	6,474.06
Mixtures	6,265.87	11,422.06
Total	90,085.57	198,321.10

The BIORAISE GIS data base has also been used to determine the collection cost of the residues at the coal power plant and transportation cost to the coal power plant, (Table II).

Table II. – Biomass costs.

Type	Average Collection Cost (Cc) (EUR/dry t)	Average Transport Cost (Ct) (EUR/dry t)	Average Total Cost (TC) (EUR/dry t)
Broadleaves	65.0	11.6	76.6
Conifers	53.4	11.8	65.2
Mixtures	60.1	9.4	69.5

Table III indicates the available energy and the average energy cost in the studied area.

Table III. – Energy from available residue.

Type	Available Energy (E) (GJ/year)	Average Energy Cost (EUR/GJ)
Broadleaves	1,429,383.63	4.34
Conifers	52,961.91	3.44
Mixtures	114,668.61	3.80
Total	1,597,014.15	-

By biomass cofiring with coal, a continuous supply of biomass would not be an issue, since the boiler plant would always have the primary fuel, coal, for 100% utilization [14].

The complexity of the coal power production and related technologies affect the risk of experiments in terms of cost in biomass cofiring, which is something that needs to be taken into consideration at a later stage.

From a technical point of view in the energy conversion technology, the risk of slagging, fouling, erosion and corrosion associated with the use of biomass can be countered by choosing appropriate biomass cofiring technologies and biomass preparation.

Fig. 2 presents the transport cost distribution in the collection area.

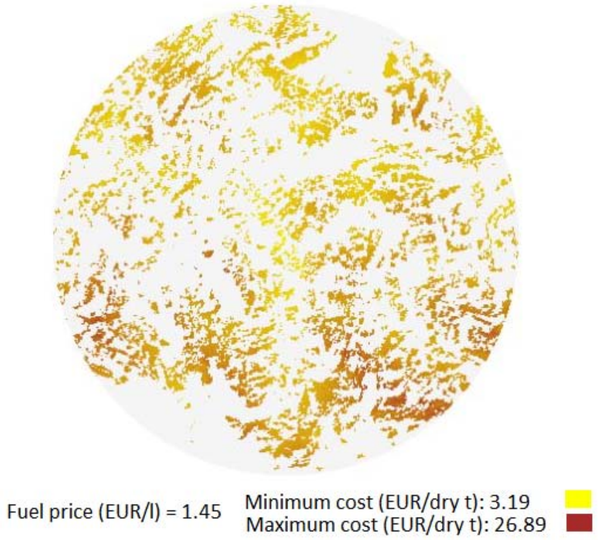

Fig. 2. Transport cost distribution in a zoom of the collection area. Adapted from [9].

Conclusion

Dissemination of biomass throughout the country should be a priority in solving our energy crisis.

Biomass co-firing in coal power plants gives an opportunity to increase the share of renewable energy sources in the primary energy balance in the country.

Biomass cofiring seems to be one of the most promising options to exploit biomass for energy use and environmental protection, its sustainability and potential are closely linked together and depend on the overall sustainability of the biomass resources.

Technical barriers to biomass cofiring are the local availability of large amounts of quality biomass as well as the cost of collection and transportation.

The potential feedstock for a coal power plant is 90 dry kt/year, which is equivalent to 24 MW_e per 7,500 operating hours and electricity efficiency of 0.4 by the biomass cofiring [15]. This is almost 50% of the total power of the plant, which generates 165 kt/year of CO_2 neutral emissions [13].

The biomass costs in the studied area are under 77 EUR/dry t.

Removing the biomass produced in forest operations means an important reduction of fire risk, which is a valuable strategy especially in protected areas.

Therefore, a detailed environmental, social and economic study, under this previous approach, could raise environmental awareness of positive effects of this biomass cofiring.

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