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Geographic distribution of economic potential of agricultural and forest biomass residual for energy use: Case study Croatia

Boris Ćosić [a,*], Zoran Stanić [b], Neven Duić [a]

[a] Department of Energy, Power Engineering and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Ivana Lučića 5, 10002 Zagreb, Croatia
[b] HEP – Obnovljivi izvori energije d.o.o., Ulica grada Vukovara 37, 10000 Zagreb, Croatia

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ABSTRACT

This paper provides methodology for regional analysis of biomass energy potential and for assessing the cost of the biomass at the power plant (PP) location considering transport distance, transport costs and size of the power plants. Also, methodology for determination of an upper-level price of the biomass which energy plant can pay to the external suppliers has been proposed. The methodology was applied on the case of Croatia and energy potential of biomass in the Croatian counties was calculated, using different methodologies, for wheat straw, corn stover and forestry residues, types of biomass considered economically viable at the moment. Results indicate that the average energy potential of wheat straw is 8.5 PJ, corn stover 7.2 PJ and forestry residues 5.9 PJ.

1. Introduction

In order to reduce greenhouse gas (GHG) emissions, increase domestic industry development, secure and diversify the supply of energy, biomass as a renewable energy resource plays an important role for reaching these goals in the industrial countries [1–7]. Because of its widespread non-commercial use, biomass is covering more than 10% of the total world primary energy supply of 479 EJ [8]. Compared to other renewable energy sources biomass has the ability to store feedstock and use it when it is required [9]. Due to diversity of biomass residues and different products that can be obtained, there are several processes that allow transforming biomass in high energy fuels that are easy to transport and handle [10,11]. Furthermore, using biomass for production of energy can significantly contribute to the job creation and economic development of rural economies and slow down migrations from these areas to cities [12–17]. Because of that, detailed and accurate estimation of the different biomass resources and their energy potential is needed.

A number of studies for estimating the potential of agricultural [18–21] and forestry residues [22–25] based on the yield, forest area, residues coefficient (i.e., straw to grain ratio), and availability factors (i.e., mechanisation losses, fraction of the residue that can't be removed from the area) have been published. Potential of agricultural and forestry residues in those studies was calculated for the regions [26–28], countries [29–32] or worldwide [33,34] and in the most cases, geographic information system (GIS) has been used to calculate the potential of agricultural and forestry residues [35,36]. In order to provide fast and precise assessment of the potential, regional distribution and economic performance of the biomass, based on the location which is the key factor for the economic viability and environmental performance, the new methodology has been proposed. Because economic benefit is the major incentive for selection of the energy plant location and biomass fuels, this paper focuses on the competitive advantage of the agricultural and forestry residues in relation to energy plant location in order to increase understanding which part of the resource base is economically attractive for use in energy plants.

In the case of the biomass feedstock, the greater the output of the plant, the greater the biomass required and the greater the average distance required to transport the biomass [37]. At the end all this results with the increase of the energy plants fuel costs and electricity generation costs. These costs can be minimised by

* Corresponding author. Tel.: +385 1 616 8242; fax: +385 1 615 6940.
E-mail addresses: boris.cosic@fsb.hr (B. Ćosić), zoran.stanic@hep.hr (Z. Stanić), neven.duic@fsb.hr (N. Duić).
URL: http://www.powerlab.fsb.hr/bcosic, http://www.powerlab.fsb.hr/neven

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Table 1
Characteristics of different types of biomass [48–55].

		Wheat straw	Corn stover	Forest residual
Straw (stover) to grain ratio [−]		0.9–1.6	0.68–1.07	–
Straw cover required for soil protection [t/ha]	Wind erosion	1.0–2.0	–	–
	Water erosion	0.5–continues grass	–	–
Biomass for livestock production [t/cattle]		0.5–1.0	–	–
Mechanisation losses in the collecting process [%]		–	20–30	–
Soil protection factor [%]		–	30–60	–
Forest residue factor [%]		–	–	12–20
LHV [GJ/t]		13.74–17.86	11.5–15.3	15.06–5.34
Humidity of biomass [%]		20–100	30–15	10–60

optimal utilisation of the vehicle payload, by optimal location and size of the energy plant and by choice of the shortest travel paths [38–42].

This paper focuses on the identification and quantification of the available biomass in the regions and analysis of the biomass costs at the power plant locations. Firstly, methodology for assessment of regional biomass potential and the cost of the biomass at the plant location was developed. Also a model for the determination of an upper-level price for the biomass which energy plant can pay to the external suppliers is proposed. Secondly, the characteristics of the case study area have been elaborated and the results of the assessment and economic analysis are presented.

2. Methodology

In order to provide a comprehensive overview on the domestic potential of the biomass for different regions, the study aimed to investigate all economically viable biomass resources based on the region needs and applicable technology. To select all economically viable biomass resource the RenewIslands/ADEG methodology has been used. This methodology was firstly developed for use on the islands [43,44] but during time, it has been upgraded for use in other regions [45], in ADEG project [46,47]. A very detailed description of RenewIslands methodology has been given in [43] and RenewIslands/ADEG methodology in [44]. Using this methodology three types of biomass were selected for further analysis, based on the region needs, its resources and the applicable technology. Selected biomass types are:

- Biomass from wheat straw
- Biomass from corn stover
- Biomass from forestry residues

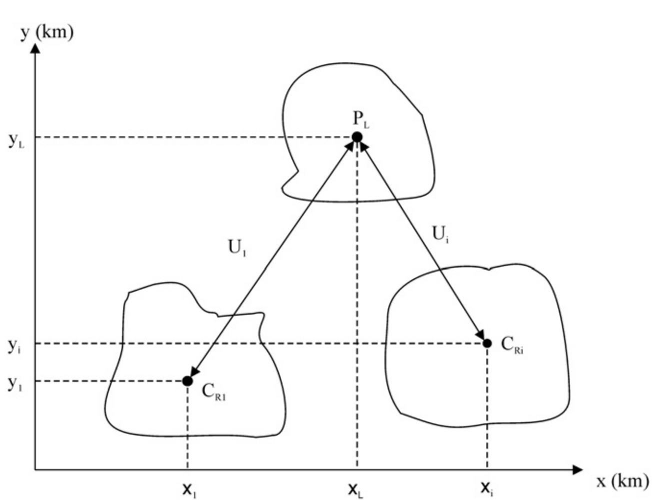

Fig. 1. Visual representation of the optimal transport distance methodology.

2.1. Technical available potential of biomass

The total potential of biomass is defined as the total annual production of agricultural and forestry residues in the regions. The total potential of biomass cannot be utilized as an energy source, because the part of the residuals needs to be left on the field for soil protection, feeding and bedding of animals and because of mechanisation losses during collecting and transportation process. Technical available potential of biomass for energy purpose is determined by subtracting quantities of residuals needed for soil protection, animal feeding and bedding from the total production of each biomass residue.

2.1.1. Agricultural residual – wheat straw

Wheat straw is an agricultural residual that remains on the soil surface after grain harvest. The amount of the residue produced on the field varies considerably with growing conditions and the amount of crop grown. Total quantity of this residual, generated during the grain harvest, is not possible to find in statistic yearbook and because of that total production of the wheat straw in the regions i (expressed in t) will be obtained as:

$$T_{WS(i)} = W_{P(i)} \times STGR_{W(i)} \quad (1)$$

where $W_{P(i)}$ represents the wheat production in region i (t) and $STGR_{W(i)}$ the wheat straw to grain ratio, which depends on the type of wheat, time of wheat seeding, cultivation of soil and total amount of nitrogen used for soil fertilization in region i (see Table 1)

Straw produced in regions should not all be removed from the fields. One part must be left on the field for the wind and water erosion control and one part of straw is used for bedding and feeding of livestock. The total amount of wheat straw required for soil protection depends on the soil texture and field slope. Coarse soil textures require large quantities of residue for control of wind erosion, and quantities needed for water erosion protection increase with the field slope. Straw needed for soil protection in the regions (expressed in t) will be obtained as:

$$S_{PW(i)} = SCP_{(i)} \times C_{A(i)} \quad (2)$$

where $SCP_{(i)}$ represents the straw cover required for soil protection in region i (t/ha) (see Table 1) and $C_{A(i)}$ the cultivated area of wheat in region i (ha).

Straw required for bedding and feeding of livestock varies from region to region and mainly depends on the duration of winter season and the number of cattle in the particular region. In regions with a large number of cattle this residue can be even higher than the potential of wheat straw in the region. Because of that these regions need to import straw from other regions which have high production of straw and small number of cattle. Requirements of wheat straw for feeding and bedding of livestock in the region i (expressed in t) will be obtained as: