POTENCIJAL, REGIONALNA RASPODJELA I CIJENA BIOMASE NA PRAGU ELEKTRANE: ANALIZA SLUČAJA ZA REPUBLIKU SRBIJU

POTENTIAL, REGIONAL DISTRIBUTION AND THE COST OF DELIVERED BIOMASS AT THE POWER PLANT LOCATION: A CASE STUDY OF THE REPUBLIC OF SERBIA

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Sadržaj: Cilj ovoga rada je određivanje tehničkog i energetskog potencijala poljoprivredne i šumske biomase te cijene biomase na pragu elektrane u Srbiji. Metodologija razvijena za određivanje potencijala i cijene biomase na pragu elektrane u Hrvatskoj primijenjena je na Republiku Srbiju. Prilikom određivanja potencijala poljoprivredne biomase koriste se godišnji prinosi žitarica dok se kod šumske biomase potencijal određuje pomoću propisanoga etata za državne šume Republike Srbije. Dobiveni rezultati pokazuju da u Srbiji postoje velike količine biomase te da su one nedostatno iskorištene u energetske svrhe. Rezultati pokazuju da je maksimalni energetski potencijal slame 37 PJ, kukuruzovine 25 PJ, a šumskih ostataka 1.7 PJ. U radu je također izračunata cijena dovoza poljoprivredne biomase do elektrane kapaciteta 300,000 tona, čija se vrijednost kreće od 40 €/t do 41.04 €/t.

Abstract: *In this paper, technical potential and delivery cost of the agricultural and forestry residues, in Serbia, has been calculated. Methodology developed for the assessment of the agricultural and forestry residues potential and delivery cost of the residues in Croatia has been applied for the case study of the Republic of Serbia. Obtained results confirm that significant quantities of residues that could be used in energy-generating purposes exist in Serbia. Maximal energy potential of the wheat straw is over 37 PJ, corn stover 25 PJ and energy potential of forestry residues in state owned forest is over 1.7 PJ. Calculated delivery cost of agricultural residues for selected location in the northern part of Serbia range between 40 €/t and 41.04 €/t.*

Key words: Technical potential, energy potential, agricultural residues, forestry residues, delivered feedstock price

1. INTRODUCTION

Renewable energy sources such as agricultural and forestry residues are getting more favoured in developing and industrialised countries, especially in the electric power supply sector. Using these residues could not only contribute to sustainable development, but also

provide employment opportunities and reduce dependency on traditional energy sources for electricity production [1-2].

Recent research in the biomass sector has been focused on the estimation of the biomass quantities from the agricultural and forestry residues based on the yield, yearly felling, residues coefficient and availability factors [3-4]. Potential in these studies has been calculated for the regions, countries or worldwide. In the case of Serbia, potential of agricultural residues has been reported in the several studies, but mostly for the Autonomous Province of Vojvodina [5-6]. However, few studies describe agricultural and forestry residues potential and the cost of supplying the power plant with these residues in Serbia.

In this work, technical and economic potential of agricultural and forestry residues has been calculated. Also, delivery cost of the biomass for different locations and size of the power plants has been analysed. Firstly, statistics data about cereals production and forest potential were analysed. Secondly, the results, i.e., biomass potential from agricultural and forestry residues, the cost of the biomass at the power plant location in the Serbia were 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 region needs and applicable technology. The selection of the biomass resources was based on the RenewIslands/ADEG methodology. This methodology was firstly developed for use on the islands [7] but during time, it has been upgraded for use in other regions [8], in ADEG project [9]. 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: wheat straw, corn stover and forestry residues.

2.1. Technical potential of agricultural and forestry residues

Wheat straw is an agricultural residual that remains on the soil surface after grain harvest. Total potential of wheat straw has been estimated by using straw to grain ratio. 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 feeding and bedding of livestock. Wheat straw needed for feeding and bedding of livestock varies from region to region and mainly depends on the cattle number, whereas amount of wheat straw required for soil protection depends on soil texture and field slope. Technical available potential of straw is obtained after subtracting the current quantities of straw needed for soil protection and for feeding and bedding of livestock in the region from the total production of wheat straw in region.

Corn stover is an agricultural residue defined as the portions of the corn plant aside from corn kernels that remain on the soil surface following grain harvest. Total potential of corn stover in the region has been estimated by using corn stover to grain ratio. It is not possible to collect all the corn stover from the field because of losses which are generated during the process of harvesting and collecting. These losses mainly depend on the mechanization used in the harvesting and collecting process. Technical available potential of corn stover is obtained after subtracting the quantities of stover needed for soil protection and losses due to collecting and harvesting process from the total production of corn stover in region.

Biomass available for energy purposes is produced during silvicultural operations aimed at

producing firewood and industrial wood and from sustainable sawlog harvest. These residuals represent the most economical and technical fraction to be used in a bioenergy system. The methodology followed is based on the current national yearly felling and biomass fraction, but only for tree branches smaller than 7 cm in diameter.

2.2. Energy potential of agricultural and forestry residues

The assessment of the biomass energy potential is based on the technical available biomass potential and the respective lower heating value of each biomass available for energy purposes. The lower heating value is different for each type of biomass and it depends on chemical structure of biomass, contents of moisture in biomass and content of hydrogen in biomass.

2.3. The cost of the biomass at the power plant location

The cost of the biomass at the power plant location depends on the cost of the biomass at the forest road or agricultural field, the transportation cost, the distance between the biomass location and the plant location and on the size of the power plant. The cost of the biomass at the power plant location (expressed in €/tons) will be obtained as:

$$G_C = \sum_{i=1}^{n} \frac{\left[C_B + \left(T_P \times U_i\right)\right] \times K_{Bi}}{P_B} \quad (1)$$

Where G_C represents the average price of the biomass at the plant location (€/ton), C_B the price of the biomass (€/ton), T_P the biomass transport cost (€/ton/km), U_i the distance between the center of the region and the plant location (km), K_{Bi} the total amount of the biomass delivered from the region i (tons) and P_B the annual fuel consumption of the power plant (tons).

3. CASE STUDY DESCRIPTION

A great part of the Serbian economy is based on agricultural production and agricultural related industry. Areas with high productivity agriculture and integrated economy are located in Vojvodina and the northern parts of Central Serbia around the Sava and the Danube rivers. Serbia has at its disposal approx. 5.1 million hectares of agricultural land of which 4.2 million hectares are cultivable land, which is above the average in comparison to EU countries [10]. Predominant crop production in Serbia is cereals which occupy 47% of total cultivable land [10]. The most important crops in the cereals sector are corn and wheat. Total corn production in 2008 was 5.9 million tons, whereas wheat production was 2.1 million tons [10]. Cereals production in Serbia is presented in Table 1. The data spans over a period of 10 years from 1999 to 2008.

Table 1. 10 year production of cereal grains in the Republic of Serbia (1999-2008)

		Wheat production			Corn production		
		Total production, t	Commercial enterprises	Family holdings	Total production, t	Commercial enterprises	Family holdings
Republic of Serbia	Avg	2,068,966	560,363	1,508,604	5,411,271	676,560	4,734,711
	Max	2,758,017	717,614	2,040,403	7,085,366	877,461	6,207,905
	Min	1,364,787	374,151	990,636	2,937,537	376,033	2,561,504

The area of forests and woodland of the Republic of Serbia is 2.7 million ha accounting for 30.7 % of the land area. The state owns 51 % of forests (1.4 million ha) while 49 % (1.3 million ha) is privately owned [11]. The state forests are managed by Public Enterprises (PE) for forest management "Srbijasume" and "Vojvodinasume". Annual allowable cut (AAC), volume and growth in Serbia state owned forests which are managed by public enterprises for forest management is presented in Table 2.

Table 2. State owned forests parameters in the Republic of Serbia [11-12]

	PE "Srbijasume"	PE "Vojvodinasume"
Volume [m3]	98,851,772	19,998,881
Growth [m3]	2,922,540	679,865
Annual allowable cut [m3]	1,090,618	646,404

4. RESULTS

4.1. Technical potential of agricultural and forestry residues

The availability of biomass from the forest and main crops in the Republic of Serbia has been evaluated. Total potential of wheat straw in Serbia is calculated by using straw to grain ratio of 1.6 [13] and data from section 3. Amount of straw required for soil protection depends on soil texture, field slope and farming practice. Given the current farming practices, an average of 1.5 t/ha was taken as a reasonable estimate of the straw to be left on the land for soil conservation in Serbia. Much of the wheat straw baled on the fields is used for animal feeding and bedding. In this work assumption of 0.6 t/cattle has been used to calculate amount of wheat straw needed for animal feeding and bedding, mostly for raising beef and dairy cattle [14]. Technical potential shown in Table 3 was calculated after deductions were made for soil conservation and for animal feeding and bedding.

Table 3. Technical potential of wheat straw in the Republic of Serbia

		Total production, t	Commercial enterprises t	Family holdings, t
Republic of Serbia	Avg	1,752,698	648,506	1,103,792
	Max	2,708,458	870,290	1,834,728
	Min	818,346	441,624	398,923

Potential of corn stover in Serbia is calculated using corn stover to grain ratio of 0.8 [15]. For estimating removable potential of corn stover assumption of 20% was used for calculating fraction on the field that goes uncollected and 50% for calculating amount of corn stover for soil protection [16]. Technical potential shown in Table 4 was calculated after deductions were made for soil conservation and mechanisation losses generated in the process of harvesting and collecting.

Table 4. Technical potential of corn stover in the Republic of Serbia

		Total production, t	Commercial enterprises, t	Family holdings, t
Republic of Serbia	Avg	1,298,705	162,374	1,136,331
	Max	1,700,488	210,591	1,489,897
	Min	705,009	90,248	614,761

Method used for calculating potential of forest residual was based on assumption that 12% [17] of the total mass of tree is forest residual which can be removed from forest and used in energy purpose. Calculated technical potential of forestry residues in Serbia, for state owned forests managed by two public enterprises, is over 200,000 m^3.

4.2. Energy potential of agricultural and forestry residues

The energy potential of agricultural and forestry residues in Serbia was estimated by using the lower heating value (LHV) and data for technical potential of agricultural and forestry residues from section 4.1. Also, for transforming technical available potential of forest residual from cubic meters to tons, density of 1 t/m^3 was used [17]. In this work, for wheat straw LHV of 13.74 GJ/t, corn stover 14.7 GJ/t and for forestry residues 8.5 GJ/t has been used [16]. Calculated energy potential of agricultural residues, wheat straw and corn stover is presented in Table 5.

Table 5. Energy potential of wheat straw and corn stover in the Republic of Serbia

		Wheat straw			Corn stover		
		Total potential, 1000 GJ	Commercial enterprises, 1000 GJ	Family holdings, 1000 GJ	Total potential, 1000 GJ	Commercial enterprises, 1000 GJ	Family holdings, 1000 GJ
Republic of Serbia	Avg	24,082	8,910	15,166	19,091	2,387	16,704
	Max	37,214	11,958	25,209	24,997	3,096	21,901
	Min	11,244	6,068	5,481	10,364	1,327	9,037

Energy potential of forestry residues is calculated for two public enterprises in Serbia, PE "Srbijasume" and PE "Vojvodinasume", Energy potential of PE "Srbijasume" is over 1.1 PJ and for PE "Vojvodinasume" energy potential is 0.66 PJ.

4.3. The cost of the biomass at the power plant location

The cost of the biomass at the location of the power plant has been calculated based on input data from section 4.1 and expression (1). For purpose of this study distance from the plant location and the center of region was obtained from the existing road maps in Serbia. The transport cost of the biomass of 0.1 €/t/km [16] and the cost of the biomass of 35 €/t [17] has been used in the calculation of the biomass cost. Size of the power plant is 300,000 tons and selected location for the power plant is City of Novi Sad, located in the northern part of Serbia. The cost of the biomass is calculated for agricultural residues due to their high potential in the northern part of Serbia. The calculated results show that the cost of delivering wheat straw to the plant location is 40 €/t and for corn stover this cost is 41.04 €/t.

5. CONCLUSION

In this paper, technical and energy potential of agricultural and forestry residues in the Republic of Serbia has been assessed. The analysis shows that large quantities of the biomass exist in the Republic of Serbia, especially in the northern part of Serbia. The results show that maximal energy potential of wheat straw in Serbia is over 37 PJ, corn stover over 25 PJ and potential of forestry residues is 1.77 PJ. An analysis performed for the selected location of the power plant indicates that the cost of the delivered biomass would range between 40 €/t and 41.04 €/t. The methodology applied for the estimation of the biomass cost didn't take into consideration competing uses of biomass with other sectors and therefore, future studies should be focused on that particular issue.

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