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BIOMASSES OF DIFFERENT *Salix* L. CLONES IN THE DECARBOXYLATION PROCESS DURING ENERGY PRODUCTION

ABSTRACT: Biomass is increasingly employed in diverse applications to achieve and enhance energy efficiency, owing to its carbon-neutral nature. This is attributed to the fact that the quantity of CO_2 released during its combustion corresponds precisely to the amount absorbed by biomass during its growth. The objective of this study is to assess the energy efficiency of biomass derived from analysed clones of fast-growing willow species in co-combustion processes with lignite at varying percentage ratios. The primary goal is to enhance the calorific value of lignite, optimize combustion and mitigate the harmful effects of combustion. The obtained results indicate that the calorific value of willow is higher than the calorific value of coal. The calorific value of coal (lignite) depends on the location of the coal deposit (field), while the calorific value of willows depends on the type of willow. Notably, clones 347 and NS 73/6 of white willow (*Salix alba)*, have the highest energy potential compared to clones B-44 of white willow and basket willow (*Salix viminalis*).

KEYWORDS: biomass, willows, decarboxylation, coal, co-combustion, energy potential, willow

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INTRODUCTION

The process of decarbonization, which has global significance, implies an increase in the participation of renewable energy sources (RES) in energy production. Biomass falls within the RES category and represents organic matter that can be of plant or animal origin. Currently, it accounts for approximately 14% of the world's total energy consumption, with developed nations utilizing a quarter of it for air protection initiatives. The remaining portion of primary energy involves the direct application of biomass in underdeveloped countries for heating in households and other purposes. Additionally, waste and residues from the wood processing industry are employed to generate energy in plants (Parrika, 2004).

Biomass is regarded by the energy community as carbon neutral because the amount of CO_2 released during its combustion represents the same amount that biomass absorbs during its growth in an energy plantation (Mann and Spath, 2001; Heller et al., 2003). The implementation of energy plantations in order to produce biomass that would be used in energy production, either independently in power plants, or through co-combustion with lignite in order to increase the calorific value, brings benefits on one hand to energy management, and on the other to ecology.

Co-combustion of biomass and lignite can satisfy both the needs of energy management and ecology, because, at the same time, the calorific value of lignite can be increased, and the emitted CO_2 reduced. Namely, the obligation of business entities is to perform land recultivation after the completion of lignite exploitation in a given area. Different plant species can be used for land recultivation, and the most suitable woody species are exactly those that are fast-growing, such as willows (*Salix* L.) and poplars (*Populus* L.). Willows grow on floodplains, in river valleys, usually along rivers or on marshy ground (Parfenov and Mazan, 1986). There are a large number of willow species, with different forms, and most often it is a tree. It can be extremely tall, up to 15 meters, and up to 1 meter in diameter, but it can also have the form of a bush or a ground plant (Oljača et al., 2017).

Multiple benefits of recultivation would be gained if energy plantations would be formed in such areas using willows. They would solve the problem of phytoremediation of heavy metals and erosion, owing to their strong root system (Ulzen-Appiah, 2002; Volk, 2002; Heller et al., 2003), and at the same time, the given area would continue to bring "gains" through the production of biomass that would be used for the production of energy.

Willows are a species that does not require complicated conditions for growth, as they are highly adaptable to various types of soil. Simultaneously, they yield well, producing a minimum of 30–40 tons per hectare of dry biomass in a very short time. They can survive on floodplains, but also on polluted and relatively degraded soil. These fast-growing woody plants, which are managed according to the short rotation principle, possess a number of characteristics suitable for the phytoremediation process, the most important of which are: a strongly developed and well-branched root system, high biomass productivity, high intensity of transpiration, as well as genetic variability (Arsenov, 2018). Due to all of the above, willows are very rewarding to use on the tailings of mining pits, where, along with the simultaneous remediation of the land, they will also provide biomass for the production of energy. Combustion of willow and coal contributes to the reduction of greenhouse gas emissions. Biomass obtained from willow, compared to coal, has almost no sulphur, contains less ash and trace metals, and depending on the combustion regime and equipment, can result in lower NO_x emissions (Conn and Tillman, 2000; Hughes, 2000; Tharakan et al., 2003a). These plantations are formed using genetically improved cloned material, with a planting density of 15,000 plants per hectare.

The biomass obtained from willows has an exceptional energy potential because the calorific value of willows can reach 19 MJ/kg. Willows belong to the Short Rotation Coppice (SRC) plantations because their harvest from energy plantations is possible every other year, for the period of up to 25 years. This is precisely why willows have been cultivated successfully for economic purposes over an extended period. Their cultivation thrives owing to their widespread geographic prevalence, adaptability to diverse environmental conditions, and robust biomass growth (Rodzkin, 2014). Willows are able to quickly colonize land surfaces without vegetation or places with poorly developed vegetative cover (Morozov, 1950). Biomass produced in such plantations has multiple applications: as fuel for the production of electricity in special generators, for the production of charcoal, for direct burning due to the low content of ash and moisture, as well as alkali metals, or simply as a source of carbon in atmospheric CO_2 (Nixon et al., 2001). Analyses of fossil fuel-based electricity generation show that producers and consumers tend to favor non-renewable energy over renewable energy (Fuchs and Arentsen, 2002; Unruh, 2002). Adopting innovations in any form is only acceptable by energy producers if it does not deviate much from the dominant technology. This is exactly why it is considered that the production of electricity by burning willow biomass in combination with other wood biomass or with coal in existing power plants is the most optimal commercial option, because it does not deviate much from the dominant technology, i.e. it does not require much investment in already existing power plants (Tillman, 2000).

The potential of willows is recognized by many countries that use them extensively for energy production. Co-combustion of biomass in coal-fired power plants, with a share of 5–20%, depending on the technology and type of biomass used, is in many cases a cost-effective option for replacing part of coal with biomass in the production of electricity, while simultaneously reducing CO_2 emissions (Tillman et. al., 2012). The moderate amount of variation in wood specific gravity can be used to select for increased energy content and reduced transportation costs (Tharakan et al., 2003b). The yield of biomass per hectare depends on the type of soil, specifically the method of wetting the soil and the content of dust and clay fractions on the researched systematic units of land (Živanov and Ivanišević, 1986), but the production of biomass from willows and its burning as a raw material for energy production provide both ecological, as well as rural development. Rodzkin et al. (2016) point out that clones of the species *Salix alba* L. and *Salix dasyclados* Wimm., as well as hybrids *S. aurita* L. and *S. dasyclados*, represent good candidates for the production of biomass on degraded lands. Currently, areas of fast-growing crops can be found in almost all EU countries, as well as in the USA and Canada (Rodzkin et al. 2015). In 2011, the area under energy plantations was, for example, in Sweden about 13,000 hectares, in Germany about 4,000 hectares, in Poland about 9,000 hectares (Dimitriou, 2011; Mola-Yudego, 2010; Rosenqvist and Dawson, 2005; Scholz, 2002; Stenhouse, 1999; Meadows et al., 1972; van Doorn, 2006).

The aim of this work is to investigate the energy efficiency of biomass of the analysed clones of fast-growing willow species in co-combustion processes with lignite in different percentage ratios.

MATERIALS AND METHODS

In this work, four willow genotypes were investigated, namely: one clone of *S. viminalis* and three clones (clone B-44, clone 347, clone NS 73/6) of *S. alba*, which are referred to in the following text as clone 1, clone 2, clone 3 and clone 4, respectively.

After three years of cultivation, in 2021, the willows were cut and dried naturally for two months. Calorific values of three lignite samples and four willow clones were determined, as well as values of the mixture of lignite and willow biomass in different proportions (5, 10, 15 and 20% of biomass). The first and second lignite samples (U_1 and U_2) were taken from two localities in the eastern part of the Kolubara MB and represent mixed samples from field B/C and field E. The third coal sample (U_3) was taken from the western part of the Kolubara basin, at the Drobilana-Kalenić loading site, and represents mixed coal from Tamnava west field and field G.

The calorific value of each of the four tested willow clones, as well as the three tested samples of lignite, was determined without correction, using the IKA C 5003 calorimeter in the accredited laboratory at the Prerada organizational unit of Kolubara MB, JSC EPS.

Numerical data obtained by measuring the calorific value of three samples of coal and the biomass of four willow genotypes, as well as by calculating the differences between the calorific value of coal and a mixture of coal with the biomass of four willow genotypes, were processed using descriptive and univariate statistical methods. Statistical analyses were performed in the computer program Statgraphics Centurion v. XVI.I. (2009; Statpoint Technologies, Inc., Warrenton, VA).

RESULTS AND DISCUSSION

Based on the tested data on the calorific value of three samples of coal in co-combustion with biomass of four willow clones (in the proportion of 5, 10, 15 and 20%), an overview was given as to the results on the possibility of improving the calorific value of coal with biomass.

Average calorific values for willow biomass (Table 1) ranged from 17,966.30 kJ/kg (clone 1) to 18,246.80 kJ/kg (clone 4), depending on the examined genotype (clone). According to Mitić (2018), willow stands out as the species that has found the greatest application in the economy due to its wide ecological valence (resistance to extreme habitat conditions), with an average calorific value of 19,300 kJ/kg of dry biomass.

The minimum value was measured for the biomass of clone 1 and was 17,952.0 kJ/kg, and the maximum – for clones 3 and 4 (18,274.0 kJ/kg). Low coefficients of variation (CV) values (0.08–0.11%) were found for the calorific value of the biomass of the studied genotypes. According to the results of the analysis of variance (ANOVA), the mean values determined for the calorific value of the biomass of four willow genotypes are statistically significantly different from each other (p = 0.0000), forming three homogeneous groups (Table 1). Based on this, it can be concluded that the calorific value of willow biomass depends on the genotype. Clone 2 is close to the values of clones 3 and 4, which is expected, given that clones 2, 3 and 4 are white willow clones, while clone 1 is a basket willow clone and is characterized by the lowest calorific value.

We can say that the *S. viminalis* (clone 1) showed the lowest energy potential, while the *S. alba* clones (clone 3 and clone 4) represented the clones with the highest energy potential. Kijo-Kleczkowska et al. (2016) point out that the calorific value of basket willow is 16,824 kJ/kg, while Karampinis et al. (2011) point out that the calorific value of willow without drying on a “dry basis” is 18,410 kJ/kg.

Table 1. Analysis of variance for the calorific value (kJ/kg) of biomass of willow genotypes

Genotype (clone)	$\bar{X}$	($\bar{\bar{X}}$)	MIN	MAX	SD	CV. (%)	F	p
Clone 1	17,966.30 c		17,952.0	17,983.0	13.54	0.08		
Clone 2	18,046.30 b	**18,124.3**	18,028.0	18,062.0	14.86	0.08	579.79	**0.0000**
Clone 3	18,237.60 a		18,209.0	18,274.0	20.35	0.11		
Clone 4	18,246.80 a		18,209.0	18,274.0	20.00	0.11		

Note: Mean values with different letters within a column are statistically significantly different from each other at the 95% confidence level.

Average calorific values for coal samples (Table 2) ranged from 12,138.03 kJ/kg (U_3) to 15,946.00 kJ/kg (U_2). The minimum value was measured for U_3 and it amounted to 12,070.0 kJ/kg, and the maximum for U_2 (15,978.0 kJ/kg). For the calorific value of the examined coal samples, low values of the coefficient of variation were established (CV) (0,21–0,43%).

Analysis of variance (ANOVA) shows that there is a statistically significant difference (p = 0.0000) between the mean values calculated for the calorific value of the coal samples and three homogeneous groups are formed (Table 2).

Table 2. Analysis of variance for calorific value (kJ/kg) of coal samples

Coal sample	$\bar{X}$	($\bar{\bar{X}}$)	MIN	MAX	SD	CV. (%)	F	*p*
U 1	12,975.00 **b**		12,905.0	13,028.0	53.93	0.42		
U 2	15,946.00 **a**	**13,686.3**	15,902.0	15,978.0	33.60	0.21	21,461.89	0.0000
U 3	12,138.03 **c**		12,070.0	12,186.0	51.76	0.43		

Note: Mean values with different letters within a column are statistically significantly different from each other at the 95% confidence level.

Accordingly, it is stated that the calorific value of coal depends on the sample, so U_2 has the highest calorific value and U_3 – the lowest. The former ($U_{2)}$ represents a mixed sample from field B/C and field E, taken from location 2, while U_3 represents a coal sample taken from the western part of the Kolubara Basin, at the Drobilana-Kalenić loading point and represents mixed coal from Tamnava west field and field G. The lower calorific value of U_3 can be attributed to the larger amount of clay present in the sample itself, compared to other samples. The data in Table 2 also show that U_2 had the highest calorific value.

In addition to differences in calorific values, there are also differences in moisture and ash content; according to these, coal U_2 stood out, while the other two had identical values of these indicators (Table 3).

Table 3. Moisture and ash content of different coal samples

Sample	Moisture (%)	Ash content (%)
U1	44.51	25.4
U2	50.94	12.3
U3	44.56	25.5

Table 4 shows the statistical results of the calorific values (kJ/kg) of the mixture of all coal samples with different proportions of biomass.

The statistical results of calorific values (kJ/kg) of the mixture of coal with different proportions of biomass show that there are no statistically significant differences between the clones and the proportion of biomass when it comes to the mixture of all coal samples.

Mean calorific values for the mixture of coal and biomass ranged from 14,126.70 kJ/kg (clone 1 added to coal as 5% biomass) to 14,613.80 kJ/kg (clone 3 added to coal as 20% biomass), depending on the tested genotype as a proportion of biomass added to coal. Based on the arithmetic mean ($\bar{\bar{X}}$) the calorific value of the mixtures increased with the increase in the proportion of added biomass, and for each clone, it had the smallest increase in calorific value when adding 5% of biomass, and the largest when adding 20%. If we look at the clones, the arithmetic mean ($\bar{\bar{X}}$) indicates that the greatest increase in thermal value is in clone 4, and the least in clone 1. Based on these data, it can be concluded that clone 4 is the clone with the highest energy potential. In second place in terms of energy potential is clone 3, followed by clone 2 and finally clone 1 with the lowest energy potential.

Table 4. Analysis of the variance of the calorific value (kJ/kg) of the mixture of coal and willow biomass

Clone	Share of biomass (%)	$\bar{X}$	$(\bar{\bar{X}})$	MIN	MAX	SD	CV	F	*p*
Clone 1	5	14,126.70 a	**14,356**	12,619.0	16,203.0	1,589.11	11.24	0.10	1.0000
	10	14,358.70 a		12,773.0	16,489.0	1,642.02	11.44		
	15	14,427.70 a		13,207.0	16,359.0	1,452.90	10.07		
	20	14,511.00 a		13,174.0	16,365.0	1,421.74	9.80		
Clone 2	5	14,140.70 a	**14,359**	12,521.0	16,417.0	1,742.65	12.32		
	10	14,271.10 a		13,002.0	15,987.0	1,298.72	9.10		
	15	14,526.30 a		13,121.0	16,579.0	1,559.22	10.73		
	20	14,498.70 a		13,259.0	16,279.0	1,350.96	9.32		
Clone 3	5	14,147.20 a	**14,372**	12,617.0	16,403.0	1,708.20	12.07		
	10	14,238.90 a		12,837.0	16,289.0	1,560.49	10.96		
	15	14,490.70 a		13,058.0	16,547.0	1,567.31	10.82		
	20	14,613.80 a		13,342.0	16,369.0	1,347.29	9.22		
Clone 4	5	14,327.30 a	**14,436**	12,801.0	16,506.0	1,663.39	11.61		
	10	14,298.00 a		12,796.0	16,476.0	1,635.92	11.44		
	15	14,551.30 a		13,192.0	16,368.0	1,398.78	9.61		
	20	14,570.60 a		13,203.0	16,476.0	1,437.15	9.86		

Note: Mean values with different letters within a column are statistically significantly different from each other at the 95% confidence level.

It should also be noted that, given that there are no significant differences between the mean values calculated for the calorific value of coal with the addition of biomass of genotypes in different proportions, it is economically justified to add 5%.

The minimum value was measured for coal with the addition of clone 1 biomass in the proportion of 10% and was 12,521.0 kJ/kg, while the maximum value was measured for coal with the addition of clone 2 biomass in the proportion of 15% (16,579.0 kJ/kg).

Low (<10%) to medium (10–20%) coefficients of variation were established for the calorific value of the mixture of coal and biomass, depending on the genotype and the proportion of biomass. Analysis of variance (ANOVA) determined that there is no statistically significant difference ($p = 1{,}0000$) between the mean values calculated for the calorific value of coal with the addition of biomass of genotypes in different proportions (Table 4). Based on this, it can be concluded that the calorific value of the mixture of coal and biomass does not depend on the genotype, as well as the proportion of biomass from 5% to 20%. Savolainen (2003) points out that with the concept of joint combustion of biomass and coal, it is possible to replace 5–30% of coal with renewable fuels – biomass.

Table 5. Analysis of variance for calorific and thermal values (kJ/kg) of mixtures of coal and willow biomass according to genotype (clone 1–4), coal sample (U_1–U_3) and biomass share (%)

Coal sample	Share of biomass (%)	$\bar{X}$	($\bar{\bar{X}}$)	Thermal difference (Δ)	Mean value of thermal differences $\bar{\bar{X}}$	SD	CV	F	*p*
Clone 1									
U_1	5	13,556.00 **g**	**13,769**	581	**794**	17.35	0.13	13,168.56	0.0000
	10	13,804.00 **e**		739		27.00	0.20		
	15	13,714.00 **f**		829		28.00	0.20		
	20	14,005.00 **d**		1030		20.00	0.14		
U_2	5	16,179.00 **c**	**16,334**	233	**388**	25.06	0.15		
	10	16,470.00 **a**		398		17.35	0.11		
	15	16,344.00 **b**		400		23.43	0.14		
	20	16,346.00 **b**		524		26.29	0.16		
U_3	5	12,645.00 **k**	**12,963**	507	**825**	23.58	0.19		
	10	12,802.00 **j**		664		31.80	0.25		
	15	13,225.00 **h**		1,087		15.87	0.12		
	20	13,182.00 **i**		1,044		7.55	0.06		
Clone 2									
U_1	5	13,476.00 **h**	13,759	551	**797**	33.00	0.24	4,354.20	0.0000
	10	13,733.30 **g**		758		24.17	0.18		
	15	13,859.00 **f**		884		23.00	0.17		
	20	13,970.00 **e**		995		36.00	0.26		
U_2	5	16,401.00 **b**	**16,296**	308	**539**	14.42	0.09		
	10	15,964.00 **d**		445		20.42	0.13		
	15	16,565.00 **a**		619		12.17	0.07		
	20	16,254.00 **c**		786		22.91	0.14		
U_3	5	12545.00 **k**	**13,022**	407	**884**	20.81	0.17		
	10	13116.00 **j**		978		108.0	0.82		
	15	13155.00 **j**		1,017		29.60	0.22		
	20	13272.00 **i**		1,134		20.81	0.16		
Clone 3									
U_1	5	13,419.70 **g**	**13,751**	445	**776**	14.05	0.10	27,345.67	0.0000
	10	13,600.70 **f**		626		11.06	0.08		
	15	13,857.00 **c**		882		7.55	0.05		
	20	14,129.30 **d**		1,154		17.16	0.12		
U_2	5	16,380.00 **b**	**16,384**	434	**438**	21.28	0.13		
	10	16,273.00 **c**		327		14.42	0.09		
	15	16,532.00 **a**		408		14.11	0.09		
	20	16,354.00 **b**		582		13.00	0.08		
U_3	5	12,642.00 **k**	**12,981**	504	**843**	26.06	0.20		
	10	12,843.00 **j**		705		8.72	0.07		
	15	13,083.00 **i**		945		21.70	0.17		
	20	13,358.00 **h**		1,220		14.00	0.10		

Coal sample	Share of biomass (%)	$\bar{X}$	($\bar{\bar{X}}$)	Thermal difference (Δ)	Mean value of thermal differences $\bar{\bar{X}}$	SD	CV	F	*p*
Clone 4									
U_1	5	13,667.00 **d**	**13,864**	692	**886**	17.00	0.12	3,405.03	0.0000
	10	13,661.00 **d**		669		98.09	0.72		
	15	14,084.00 **c**		1,109		65.87	0.47		
	20	14,047.70 **c**		1,073		40.50	0.29		
U_2	5	16,491.00 **a**	**16,423**	376	**452**	17.35	0.11		
	10	16,422.00 **ab**		402		47.15	0.29		
	15	16,348.00 **b**		483		25.71	0.16		
	20	16,428.00 **a**		545		41.68	0.25		
U_3	5	12,824.00 **f**	**13,023**	686	**885**	24.06	0.19		
	10	12,811.00 **f**		673		24.27	0.19		
	15	13,222.00 **e**		1,084		32.79	0.25		
	20	13,236.00 **e**		1,098		37.00	0.28		

Note: Mean values with different letters within a column are statistically significantly different from each other at the 95% confidence level.

The mean calorific values of the mixture of coal and willow biomass ranged from 12,545.00 kJ/kg (coal sample 3 with 5% biomass of clone 2) to 16,565.00 kJ/kg (coal sample 2 with 15% biomass of clone 2) depending on examined genotype (clone), coal sample and biomass share. For the calorific values of the examined mixtures of coal with biomass, low values of the coefficient of variation were established (CV=0.05–0.82%). According to the results of the analysis of variance (ANOVA), the mean values determined for the calorific value of the mixture of coal samples with the biomass of willow clones are statistically significantly different from each other ($p = 0.0000$) (Table 5).

It can be stated that the improvement of the calorific value of coal with willow biomass depends on the genotype, coal sample and biomass share, so the mixtures of coal sample 2 with 15% biomass of clones 2 or 3 have the highest calorific value, and the mixture of coal sample 3 with 5% of clone biomass 2 – the lowest calorific value. At the same time, the addition of only 5% of biomass of clone 4 to coal sample 2 gives a solid improvement in the calorific value, because the addition of three times less biomass of this clone to coal sample 2, compared to clones 2 and 3, only gives a minor 0.2–0.4% improvement in the calorific value of coal. With the addition of biomass, the calorific difference increased, with an increase in the amount of added biomass from 5–20%.

By analysing table 5, the greatest heterogeneity was obtained in clones 1,2,3, where there are 11 groups of variability, and the least in clone 4, with 7 groups of variability. When it comes to the type of coal and the share of biomass, the smallest dependence on the amount of biomass and type of coal is observed in clone 4, while coal U2 is the best and takes first place (a) regardless of the clone.

Thermal values of coal and willow clones clearly show that there are differences both between the types of coal and the willow clones (Table 6).

Table 6. Mean value of calorific differences ($\bar{\bar{X}}$) of coal types and willow clones regardless of the proportion of willow biomass (kJ/kg)

Type of coal	Clone 1	Clone 2	Clone 3	Clone 4	$\bar{X}$
U_1	794	797	776	886	**813**
U_2	388	539	438	452	**455**
U_3	825	883	843	885	**859**
$\bar{X}$	**669**	**740**	**685**	**741**	–

The type of coal contributes the least to the increase in calorific value when willow clones are added, which is understandable considering that it is the best coal in terms of calorific value. Among the willow clones, clone 4 and clone 2 stand out, the other two are similar. The addition of willow biomass to coal is most effective with U3, which is the worst thermally; then with U1 and finally with the best quality coal U2, the thermal difference is 455 (kJ/kg).

CONCLUSION

The application of biomass in co-combustion with lignite could successfully increase the calorific value of coal and thus save coal in the production of energy, but also reduce the carbon taxes that will be present in the future, thus properly following the path of decarbonization, with the aim of protecting and preserving the environment.

Based on the results obtained in this paper, the following can be concluded:

– The calorific value of the mixture of coal and biomass depends on the type of coal, as well as on the genotype and the proportion of the willow biomass. The basket willow, *Salix viminalis*, showed the lowest calorific potential compared to the examined white willow genotypes (*Salix alba*);

– Clones 347 and NS 73/6 (clones 3 and 4) of white willow showed the greatest energy potential compared to clones B-44 (clone 2) of white willow and basket willow (clone 1);

– The lignite sample taken at the Drobilana-Kalenić loading site, which represents mixed coal from the Tamnava west field and field G, is the coal sample with the lowest calorific value (U3), followed by sample U_1 which represents a mixed sample from field B/C and field E, while sample U_2 has the highest thermal value, which represents a mixed sample from field B/C and field E, but was taken from a different location compared to the sample U_1;

– With an increase in the proportion of willow biomass (5–20%) in coal, regardless of the genotype, the calorific difference (Δ) of coal increases and it is generally the largest with the highest proportion of willow biomass;

– The addition of willow biomass to coal is most effective with U3, which is the worst calorically, then with U1 and finally, with the best quality coal U2, the thermal difference is the smallest, so the most optimal is the co-combustion of biomass and low-calorie lignite;

– Although the thermal value of the mixture of biomass and coal increases with the increase in the proportion of willow biomass, it is economically justified to add 5–10% of biomass.

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ОРИГИНАЛНИ ЧЛАНАК
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ПРИМЕНА БИОМАСЕ РАЗЛИЧИТИХ КЛОНОВА ИЗ РОДА *Salix* L. У ПРОЦЕСУ ДЕКАРБОКСИЛАЦИЈЕ ПРИ ПРОИЗВОДЊИ ЕНЕРГИЈЕ

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РЕЗИМЕ: Биомаса се све више користи у разним видовима добијања или повећања енергетске ефикасности јер је карбонски неутрална, односно количина CO_2 која се ослободи приликом њеног сагоревања представља исту ону количину коју биомаса апсорбује током свог раста. Циљ овог рада је да се испита каква је енергетска ефикасност биомасе анализираних клонова брзорастућих врста врба у процесима косагоревања са лигнитом у различитим процентуалним односима, а све у циљу повећања калоријске вредности лигнита бољег сагоревања и смањења штетних ефеката сагоревања. Добијени резултати указују да је калоријска вредност врба виша од калоријских вредности угља. Калоријска вредност угља (лигнита) зависи од налазишта угља (поља), док калоријска вредност врба зависи од врста врба. Утврђено је да клонови 347 и NS 73/6 беле врбе (*Salix alba*), поседују највећи енергетски потенцијал у поређењу са клоновима B-44 беле врбе и кошарачке врбе (*S. viminalis*).

КЉУЧНЕ РЕЧИ: биомаса, врбе, декарбоксилација, енергетски потенцијал, косагоревање, угаљ