OPPORTUNITIES OF SOLID RENEWABLE FUELS FOR (CO-)COMBUSTION WITH COAL IN POWER PLANTS IN SERBIA

by

Predrag M. RADOVANOVIĆ, Marina P. JOVANOVIĆ*, and Aleksandar M. ERIĆ

Laboratory for Thermal Engineering and Energy, Vinča Institute of Nuclear Sciences,
University of Belgrade, Belgrade, Serbia

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In the process of accession to the EU, Republic of Serbia will be obliged to achieve an appropriate share of renewable sources in primary energy consumption in addition to control the emission of carbon dioxide in order to comply with EU's energy policy. In this paper the potential of the production of the so called "green electricity" from biomass and waste in Republic of Serbia is shown with particular attention to the Electric Power Industry of Serbia, as the largest potential producer of electricity from renewable fuels. Based both on the available total quantity and heating value of non-hazardous solid waste material (municipal and industrial), the calculation of the total available energy potential of waste in Republic of Serbia (by regions) was performed for the state of the 2010th *and the projections of waste quantity growth until 2020*th*. Also, for the same time period, the available amount of waste biomass suitable for (co-)combustion with coal was estimated, as the respective energy potential. The possible energy effects of (co-)combustion in power plants as well as reduced emissions of* CO_2 *with significant financial impact are demonstrated. Actually, this paper demonstrates necessity and techno-economic justification (co-)combustion of renewable fuel with coal in thermal power plants in Serbia.*

Key words: *solid renewable fuels, (co-)combustion, green electricity*

Introduction

Recently energy policy of EU-27 is based on the prediction that the increase of energy consumption will be higher for 11% in 2030 in comparison to 2005, while the energy import dependency increase from 50% to 70% between 2005 and 2030 [1, 2]. Energy market has no long-term stability characteristics, current greenhouse gaseous emissions (GHG) lead to a rise in global average temperature ($T = 0.6$ °C), which will have serious consequences for ecosystems. Because of the inexorable growth of energy consumption, approach of EU to the own energy strategy regarding the production of electricity and heat by 2030, is based in increasing the use of green electricity from renewable energy resources such as biomass and waste.

There is a noticeable tendency (especially in the EU members) increasing the use of renewable fuels, as a partial substitute for fossil fuels, in processes of combustion and (co-)com-

* Corresponding author; e-mail: marinaj@vinca.rs

bustion for energy production. According to available statistics in the EU-27 biomass and waste account for 1/5 in the production of electricity from green sources including the production of hydro power plants [3]. The EU strategy in electricity production from waste and biomass in thermal power plants (TPP) of EU-27 aims to achieve about 11 % up to 2030 and it presents 7 % of total electricity produced (about 4.4 million GWh) [2].

Although the available quantities of biomass present very significant potential, the biomass is sporadically used in several power stations in Serbia, but in quantities that have no influence on the energy balance of the country, while firewood is still almost entirely used for households heating on traditional inefficient way. When considering waste materials, which may also represent a significant domestic potential energy, the use of these materials in Serbia does not exist. Also, as in the neighboring countries, there is no organized collection, sorting and recycling of waste materials, besides the paper.

This study indicates necessity and techno-economic justification co-firing of renewable fuel with coal in Electric Power Industry of Serbia (EPS) thermal power plants [4], where domestic solid renewable fuels from non-hazardous solid waste materials (municipal and industrial) and biomass wastes for obtaining heat and/or electricity are defined. Also, their quantities and annual potential energy that can be (co-)combustion with coal in EPS power plants up to 2020 were estimated.

Methodology of the development process of combustion of solid renewable fuel

Investigation of developing of biomass combustion technologies began about four decades ago, in the Laboratory for thermal engineering and energy, of the Vinča Institute of Nuclear Sciences, Belgrade. During the scientific and development research, the scientific and technical results were achieved in the field of characterization of the combustion, gasification and making balance of biomass potential in the country.

Verified scientific results, realized during these investigations, were made throughout the preparation of master and doctoral theses [5-9], the publication of scientific papers in international journals, several are placed in references [10-18], as well as preparation of studies [4, 19].

Based on the results of scientific research that is taking place in several stages, an appropriate developmental research was carried out, with the aim of mastering the technology of combustion and gasification of biomass. For these purposes, different experimental apparatus and furnaces for research the processes of combustion and gasification have been developed [5, 6]. Thereby, the different types of biomass: corncobs, briquettes of different types of agricultural waste residues, woody waste and *etc*. were investigated.

One of the direct results of multiannual scientific research and process, is to establish a methodology and development of an experimental facility for the characterization of biomass as a fuel in a fluidized bed combustion [6]. In the last ten years, the research of baled biomass combustion, so-called "cigarette" way combustion, has been performed [17-23]. In order to examine the problems of transport processes of cigarette combustion technology, own experimental methods have been developed, with aim to determine the thermo-physical properties of various types of biomass [18-20].

Another important direct result of both types of research is to establish a methodology and development of appropriate experimental apparatus/combustion furnaces, in order to provide a basis for the development of various industrial furnaces and boiler plants that burn different types of agricultural waste biomass [21-25]. Based on these researches, in the last decade of the 20th century, the domestic industry has produced several furnaces for driers and boilers with fluidized bed combustion of different types of biomass, power from 1.5 to 3.0 MWt.

The first results of research of the energy potential of biomass in Serbia were presented in the literature [21, 22]. Also, the necessary conditions and measures to achieve the use of biomass for energy purposes, as well as the possibilities and the importance of the use of biomass are presented in [10, 23, 24]. Recent research results of available quantities and the energy potential of biomass suitable for (co-)combustion with coal in EPS power plants, are placed in the studies [4, 19].

In a study [4], which results are presented herein, refers to estimates of energy potential and amount of solid, non-hazardous industrial and municipal wastes (solid recovery fuel), also suitable for (co-)combustion with coal in power plants in Serbia. For this purpose, the methodology was used, that was adopted during the working of the international EU FP6 project RECOFUEL (Demonstration of co-firing of solid recovered fuels in European lignite fired power plants and implementation of a sustainable waste to energy technology in large scale energy production [26]).

Available quantities of solid renewable fuels and their projections up to 2020

Renewal used of solid renewable materials (from biomass and waste) for energy production has several positive effects and represents necessity in modern societies. (Co-)combustion of solid renewable fuels with fossil fuels, mainly biomass due to the relatively low investment cost, indicates a promising alternative with a view to increase the share of renewable fuels in the total energy production. The advantages of (co-)combustion of solid renewable fuels are: saving of primary energy source (usually fossil fuels), reduced dependence of imported fossil fuels, lower emission values of harmful gaseous, reduce CH_4 and overall pollutions from landfills when the solid renewable fuel derived from wastes thereby reduction of risk on human health, increasing employment and development of rural areas. On the other hand, due to higher investment and operational cost effectiveness, countries with coal-fired power plants are committed to (co-)combustion of solid renewable sources instead of construction of special facilities in which only renewable energy fuels use [4].

Although Serbia has solid potential energy from waste materials, an application of biomass and waste materials in energy purposes late. There is no continuous monitoring of waste, composting and incineration, municipal wastes is disposed in landfills without treatment, industrial waste is disposed in landfills together with municipal wastes [27, 28]. When considering use of biomass waste, developed market and business models as base for maintaining chain for supply biomass from individual producers to public consumers does not exist. However, there are several examples from individual producers to commercial consumers (energy producers for thermal energy production).

This situation is caused by different factors, including the fact that the domestic market does not have adequate stable, long-term and significant demand of solid renewable fuels despite the established financial incentives for the production of "green electricity" and heat.

In a study [4] it is emphasized that the EPS represents the greatest potential energy producer from renewable fuels by (co-)combustion with coal likely, if its owner for any reason define to use renewable energy sources, could positively and relatively quick reverse existing state. Therefore, in study [4] which is based on the criteria (from practice in the EU), detailed analysis and calculated available energy potential of renewable solid fuels (derived from wastes biomass and municipal and non-hazardous industrial wastes) in Serbia (without data from territory of Kosovo and Metohija) and especially for domestic coal-fired power plant was done.

Solid recovery fuel from non-hazardous wastes

Last two decades in the world solid renewable fuel (solid recovery fuel – SRF) is produced from harmless wastes materials (municipal solid and industrial waste). In order to use as fuel first the wastes must be classified and then from separated harmless materials, which are suitable for combustion, SRF is produced in the facilities for mechanical, thermal and biological treatment, fig. 1. The production process must satisfy the requirements of prCEN/TS 15359 (set of technical specifications for the production and trade with SRF). Among the other factors, the amount of refinery waste or produced of SRF influence on the economy of the plant as well as taxes for collection and production of SRF. On the other hand, expenses for waste materials and SRF transport to the combustion place influence on the possible locations for the production of SRF [4].

Figure 1. Solid recovery fuel (SRF) [11]

The advantages of using SRF compared to coal are: the long-term availability (renewable fuel), the heating value is great or equable in respect to lignite (*Hd* = 18.7 MJ/kg for SRF, *Hd* = 8 MJ/kg for lignite), the relatively low production cost, part of the total emission of CO_2 is taken in consideration because the large part of SRF is biological origin (50-80%).

According to the method of preparation and mixing secondary fuel with coal, there are three basic types of combustion: directly, indirectly and parallel [29, 30]. In case of direct combustion option, SRF and coal are simultaneously introduced into the boiler. Directly (co-)combustion can be carried out in various ways depending on the place were secondary fuel blend with base fuel (on conveyor belts, in a bunker, in mills and canals between the mills and boiler).

The total annual available amount of wastes and quantity suitable for (co-)combustion in Serbia

For the calculation of the total municipal solid waste (MSW) in Serbia the available official statistics were used [31], and data of quantities for industrial solid waste (ISW) were taken from [32]. Morphological composition of the waste materials was the basis for the calculation amount of combustible part of waste suitable for combustion. The following categories of MSW are taken into calculation [33, 34]: paper, paperboard, wax coated cardboard, aluminum cardboard, plastic packaging, textiles, leather, household wastes and similar wastes; and the following categories of ISW [32]: paper and cardboard, plastic packaging, wood, household wastes (furniture, parquets, windows, doors). Based on average values of ultimate analysis the heating value of MSW available for combustion of 18.700 kJ/kg is calculated [4, 34]. Since the ultimate analysis was performed for the urban environment, which is one of the most developed in the country, in a further calculation was adopted *Hd* = 16 MJ/kg according to experience [26] (15% lower than computed value). The quantity of combustible ISW is considerably less than amount of combustible MSW. Therefore, in the further analysis, the same heating value of mixed combustible quantities (sum of MSW and ISW) of 16.000 kJ/kg was adopted.

According to the modern waste treatment in the EU [35, 36], the priority in waste management should have a recycling and re-utilization of waste use. Half of the total quantity of paper and cardboard, needed for recycling, is reduced from the total amount of the waste materials available for combustion. Sludge and residue of MSW and ISW are not taken into ac-count because of the currently slightly amount as well as of the existing technology of coal combustion in power plants of EPS is not suitable for the co-combustion of liquid waste and the specific handling of these substances.

Based on estimated total quantity of waste materials (municipal and industrial) available for combustion for 2010 in Serbia and their heating value the calculation of energy waste potential was performed. Total amount of waste available for combustion for 2010 as well as prediction up to 2020 is placed in tab. 1, regard to macro-economic parameters in RS when increasing annual amount of MSW and industrial waste of 2% and of 3%, respectively, was projected [37]. In addition, the total quantity of wastes data would be taken to an accuracy of ±7.5%. Based on estimated quantity of waste materials available for combustion in Serbia and the proper criteria, local landfills were clustered into regions by regional districts or groups of districts, in order to examine possible sites for SRF production and (co-)combustion with coal in power plants of EPS.

The calculated values of wastes available for combustion with coal in groups of districts (I-IV), for a period of 2010-2020, are shown in fig. 2 (borders of districts as a white line). Except districts in Kosovo and Metohija (25-29), following regions are not included in defined groups of district: Toplički (21), Jablanica (23), and Pčinjski (24) because of small amounts of waste. Approximately, half of the available potential of SRF production in Serbia is possible to organize in a regional district II, in which about 2/3 of the amount of waste comes from the Belgrade City.

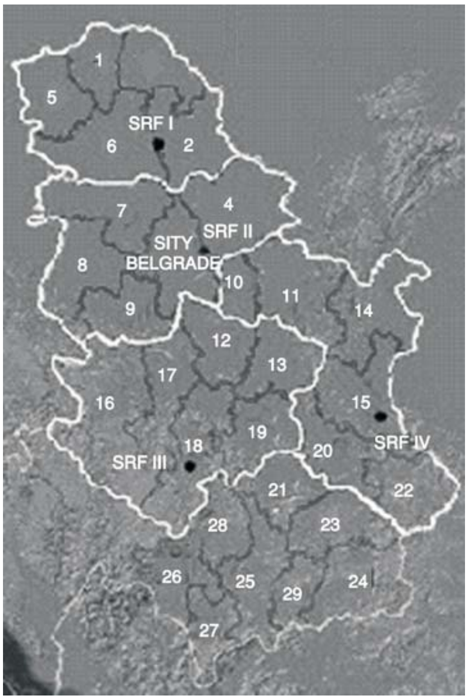

Figure 2. Territorially grouping of regions in four group of regional districts I-IV in Serbia where total quantity of wastes suitable for combustion is calculated

According to the criteria such as: quantities of wastes suitable for (co-)firing with coal, proposed location of the plant for the SRF production (tabs. 1), and taking into account the economically suitable criterion for SRF transport by road (up to 200 km) to power plant, the obtained quantities of waste for 2010th for EPS's thermal power plants are:

– For the TPP (TENT-A, TENT-B, or TPP "Kolubara") – from the regional districts I and II, is available about 540,000 t/year of wastes suitable for (co-)combustion with heat quantity of 210 ktoe/year, respectively, during 6,000 h/year the mean power output of units is 130 MW$_e$. It is noted that both groups of

districts and both regional landfills could be located along navigable parts of the Danube and Sava rivers. Water transport of SRF to TENT could be used as a cheapest way.
– For TPP "Morava", or plant "Kostolac" from regional district III and IV is available around 240,000 t per year of waste suitable for (co-)combustion with heat quantity about 90 ktoe per year, respectively, during 6,000 h per year the mean power output of units is 60 MW_e.

Table 1. Total amount of wastes (SRF) available for (co-)combustion with coal in Serbia

Regional district	Total quantity of wastes available for (co-)combustion (SRF) [t per year/ktoe per year]			
	2010	2015	2020	Possible location of SRF
District I Regions: 1, 2, 3, 5, 6	164,200/63	182,700/70	202,000/77.15	Middle Banat district, beside the Danube river
District II Regions: 4, 7, 8, 9, and Belgrade city	380,100/145	423,100/162	467,500/179	Between Belgrade and Obrenovac (beside the Sava river) or existing landfill in Vinča near Belgrade
District III Regions: 12, 13, 16, 17, 18, 19, Raška district	150,200/57	161,400/62	185,300/71	Raška district
District IV Regions: 10, 11, 14, 15, 20, 22, Zaječar district	88,900/34	98,800/38	108,900/42	Zaječar district
TOTAL	783,500/299	866,300/331	963,700/368	

Fuel from biomass

The use of biomass in the energy sector implies energy recovery from the biodegradable fraction of waste, residues from agriculture, forestry and industry. In recent years, it becomes increasingly actual finding the most cost efficient ways to get energy from biomass, low energy, *i. e*. waste materials derived from the processing of agricultural crops, wood, paper and others. The process of chemical conversion of biomass into heat energy can be perform to its direct combustion, or combustion products of gasification of biomass or products of other processes by which biomass can be pre-submitted. CO_2 produced during the combustion of biomass are re-absorbed by the process of photosynthesis in plants and in the calculations assumed that the combustion of biomass is CO_2 neutral. Table 2 shows the ultimate analysis of combustible matter the most common types of biomass in Serbia and the Kolubara lignite.

According to the data presented in tab. 2 above it can be noticed that the share of carbon of the Kolubara lignite bigger than in the biomass, and oxygen content lower as a result of long-term processes of lignite carbonization. The content of nitrogen and hydrogen is approximate, while the percentage of sulfur is much higher than in the biomass, where is almost negligible. Extremely small contents of sulfur and mineral matters in biomass cause low emission of SO_2. Also, the ash content is almost negligible. It can be concluded that, from an environmental standpoint and from the standpoint of sustainable development, biomass very friendly energy source.

Table 2. Chemical composition of the domestic biomass and Kolubara lignite [4, 19]

Type of fuel	C	H	O	N	S
	[mass.%]				
Agricultural biomass	45-52	5-7.5	40-47	0.5-2.8	0.1-0.2
Forest biomass	50-54	6-6.7	40-44	0.1-0.6	0.01-0.1
Kolubara lignite	57-65	5.8-6	25-26	2.5-3	0.35-0.79

The proximate analysis of domestic biomass and coal are different, except for the fixed carbon content, tab. 3. The moisture and ash content are much higher for coal than for biomass after harvest. Consequently, net caloric value of such biomass is significantly higher, and its use as a fuel is more favorable than coal from the standpoint of the total content of ballast and pollutants.

Table 3. Proximate analysis of domestic biomass and Kolubara lignite

Type of fuel	Moisture [%]	Volatile [%]	C_{fix} [%]	Ash [%]	Net caloric value [MJkg^{-1}]
Agricultural biomass	6-11	55-73	12-21	1-5	13-16
Forest biomass	7-15	67-76	12-23	0.5-4	12-15
Kolubara lignite	43-50	13-25	12-15	12-22	6-8.8

Low bulk density cause a problems in biomass use, which is for the agricultural residues in range from 100-200 kg/m^3, while for the domestic lignite of 500-600 kg/m^3 which requires larger furnaces and the storage bunkers. Furthermore, the effect of inhomogeneity size and shape is the main problem in the construction of furnaces and feeding unit. Significantly lower melting temperature of biomass ash then melting temperature of coal ash can cause problems with using biomass.

Total quantities of biomass wastes available for (co-)combustion in Serbia

In this paper, the residues from agricultural and industrial production, which can be classified into five groups, are taken into account. The current amount of biomass in Serbia, available for obtained energy in the process of co-combustion, as well as their potential energy [19, 38-45], without analyzing the possibility of growing energy plants on abandoned areas, are shown in tab. 4.

Analysis of transport costs [4, 45] showed that the profitable transport of residues of agricultural and forest biomass is in case of distance until 50 km.

Analysis based on the thermal power plants surroundings, it was found that in those areas the dominant agricultural (wheat straw and corn stover) and wood (forest wood) biomass. Their remains are calculated in accordance with the described criteria and are shown in tab. 5 (for power plants). In order to calculate the energy potential of available biomass, average lower heating value of agricultural and woody biomass is 13 MJ/kg and 11 MJ/kg, respectively, are used.

In calculation the available quantities, the amount of biomass from the other side of the river which can be transported to the power plant both by river and by land transport means is taken into account, tab. 5.

Table 4. The energy potential of biomass in Serbia classified into five groups

Types of biomass	Quantity ($\cdot 10^3$)	Potential energy [ktoe per year]
The remains of crops[1] [t per year]	3,061.6	955.3
Residues fruit growing [t per year]	1,119.3	467.8
Forestry and wood processing residues[2] [m^3 per year]	1,263.2	221.0
The remains of the tree outside the forest [m^3 per year]	201.2	34.3
Residues from livestock production-liquid manure [m^3 per year]	3,591.6	42.2
TOTAL:		1,720.6

[1] It is known from experience in order to utilization for another purposes, only 1/3 of total amount of this kind of biomass is available for combustion,
[2] Residues occurring in the process of logging and wood processing

Table 5. Amount of biomass available for coal-fired power plants of EPS

TPP	Parametar	Wheat straw	Corn stover	Wood
TENT-A	Biomass [t/year]	124,282	208,423	42,339
	Potential energy [ktoe/year]	103.30		11.13
	Total [ktoe/year]	114.43		
TENT-B	Biomass [t/year]	103,666	181,896	53,154
	Potential energy [ktoe/year]	88.61		13.97
	Total [ktoe/year)	102.58		
TEKOL	Biomass [t/year]	90,013	140,620	52,906
	Potential energy [ktoe/year]	71.65		13.85
	Total [ktoe/year)]	85.50		
TEKO-A and B	Biomass [t/year]	59,871	172,568	45,645
	Potential energy [ktoe/year]	72.18		12.00
	Total [ktoe/year]	84.18		
"MORAVA"	Biomass [t/year]	68,625	162,365	63,990
	Potential energy [ktoe/year]	71.65		16.81
	Total [ktoe/year]	88.46		

In accordance to vicinity of the location of thermal power plants (TENT-A, TENT-B and "Kolubara", as well as "Kostolac A", "Kostolac B", and "Morava"), an area of 50 km radius around the each power plant partially overlap, so that the total potential of biomass for all power plants is not equal to the sum of the available quantities of biomass of each power plant. Therefore, the total potential of the biomass available for all coal-fired power plants of EPS is given in tab. 6.

Total potential energy of solid renewable fuels for coal-fired power plants of EPS

Total potential energy of solid renewable fuels and possible share of solid renewable fuels in electricity production in coal-fired power plants in 2010 is placed in tab. 6.

Table 6. Total potential energy of solid renewable fuels available for EPS's coal-fired power plants

Renewable fuels	Quantity [t per year]	Energy potential [ktoe per year]
Wheat straw	221,148	216.2
Corn stover	474,881	
Residues occurring in the process of harvesting and processing wood	133,725	35.1
Fuel from municipal and industrial waste	780,000	300.0
Total:	1,609,754	551.3

In case that total available quantities of solid renewable fuels (co-)firing with coal in EPS power plants, the possible shares of electricity from these fuels in relation to the electrical from coal are presented in tab. 7.

Table 7. Possible shares of solid renewable fuels in electricity production in power plants in EPS for 2010

TPP	Electricity production in 2010 [GWh_e]	Potential of SRF [GWh_e per year]	Share of SRF [%]	Biomass potential [GWh_e per year]	Share of biomass [%]	Total share of solid renewable fuels [%]
TENT-A						
TENT-B	17,775	764.6	4.3	553.9	3.1	7.4
"Kolubara"						
"Morava"						
"Kostolac"-A	5,387	317.2	5.9	331.6	6.2	12.1
"Kostolac"-B						
Share of solid renewable fuels for all of six thermal power plants						8.4

Maximum amount of solid renewable fuels that combustion in TENT-A, TENT-B, and "Kolubara" power plants, proportionally distributed by units in relation to electricity production, does not exceed 10% of the heat quantity for each units. For "Kostolac"-A, "Kostolac"-B, and "Morava" power plants the ratio is less favorable and exceeding 10% of the heat quantity. When consideration all power plants in EPS, share of solid renewable sources in electricity production could be 8% in 2010.

These analyses (described in [4]) are needful for several reasons but the most important are the following two:

- according to the past experience, the combustion of solid renewable fuels, approximately 5-10%, in existing plants is possible to achieve in a direct way, *i. e.* using the existing infrastructure with minimal technical changing and investments (tab. 8), and

– reduced annual combustion of coal (coal replace with solid renewable fuels), about 3 million tons, induces reducing overall emissions of pollutants. For example, CO_2 reduction of 1,900 kt per year would be obtained in relation to the total emission of CO_2 of 30,330 kt from coal-fired power plants of EPS in 2008, [46, 47]. Applying emission trading system, decreasing of CO_2 for 6.3 % amount of 42 [million€/year] at a cost of 22 €/tCO_2 could be obtained.

Table 8. Average investment and production cost of electricity for different renewable energy sources in USA[48]

Technology	(Co-)combustion of biomass	Geothermal energy	Solar energy	Wind energy	Landfill gas	Biomass 100%
Investment cost [USA$/kW]	50-230*	2000	3000	700	1000	1100
Capacity factor	0.75	0.9	0.4	0.25	0.73	0.73
Fuel cost [USA$/GJ]	0.85-1.3	0	0	0	0	2.00
Production cost of energy [0.01USA$/kWh]	1.24-2.75	4.63	14.6	6.23	4.13	5.18

* Depending of the type of (co-)combustion (directly, indirectly or paralel)

The completeness of domestic legislation

In the EU-27, national regulations of (co-)combustion of solid renewable fuels are made in accordance with EC directives. Thus, each power plant that using SRF and biomass waste as a fuel must fulfill requirements of the waste incineration directive (WID) [49] and the large combustion plant directive (LCPD) [50]. WID relating to facilities for energy production in processes for combustion and (co-)combustion of SRF, and LCPD is applied to power plants, respectively, furnaces with power greater than 50 MW_t. In both directives limit values for emissions of CO_2, NO_x, and particulars are described. Renewable Energy Sources Directive [51] encourages the development of SRF market and renewable energy use. A number of EU directives related to the use of biomass in an electric power industry [51]. Therefore, the directive on integrated pollution and prevention control directive (IPPC), 2008/1/EC [52] provides the best available technology (BAT) [53] which minimize the pollution in industry sub-sectors, including large combustion plants (extensively about EU directives and national regulations in [4]).

Existing national legislation on (co-)combustion of solid renewable fuels was done an almost complete as the current legislation of the EU. Concerning (co-)firing of waste materials, in Serbia, there is an adequate basic legislation: Law on waste management (2009, *etc*.), [54], law on environmental protection (2009, use wastes as fuel) [55], Regulation on limit values of pollutants in the air (mostly harmonized with the IPCC and LCPD Directive) and Regulation on wastes thermal treatment (an implementation of the Directive 2000/76/EC) [48, 56]. Further, standardized fuels from solid waste (SRF), the limits of emissions in (co-)combustion processes of SRF in plants for energy production, monitoring of emissions, the best available techniques for (co-)combustion of wastes are not defined.

According to the law on waste management and the law on environmental protection, before adoption of appropriate legal documents that more determined the application of SRF combustion, if the EPS wants to obtain a license for the SRF (co-)combustion in boilers, a study on the impact of the application of SRF in boiler power plants on the environment have to be done. In case for the use of biomass (co-)combustion the legislation is complete.

In the process of joining the European Union, Serbia has been accepted and will be accepted regulations on environmental protection (for example, The First National Communication of the Serbia [46] notes that the largest emissions of greenhouse gases released from energy sector at production of electricity). Apart from that, the awareness of citizens of Serbia as well as the need to reduce pollution from industrial facilities increased over time. In near future, it will have a very large impact on the functioning of the Electric Power Industry of Serbia and obligations in investment potential for equipment to reduce harmful emissions and pollution in general.

Conclusions

In this paper the available quantities of solid renewable fuels for the (co-)combustion with coal in power plants of EPS: TENT for A and B, Kolubara, Morava, and Kostolac A and B are presented. Analysis included solid renewable fuels from waste materials and biomass from 2010 to 2020.

Based on very restrictive methodology applied in the study [4] the potential energy of solid renewable fuels in Serbia (without data from territory of Kosovo and Metohija) is not negligible. It was estimated approximately of 1,720 ktoe of biomass and 300 ktoe of non-hazardous wastes in 2010 in Serbia. Applying (co-)combustion with coal in power plants, EPS could be used potential of biomass and waste approximately of 251 ktoe per year and 300 ktoe per year, respectively. It indicates total potential of 550 ktoe per year, electricity production of about 2,000 GWh or share of electricity production of 8.4 % in thermal power plants. Additionally, it was indicated that the EPS should have the interest to continue with the analysis of the possibilities of using solid renewable energy resources in units of power plants and the opportunity to continue working of units in power plants which life time is over (or and of life time) such as the small blocks in TPP "Kolubara"-A and TPP "Morava".

When using the potential energy of solid renewable fuels of 550 ktoe in 2010 (and growing by 3% per year until 2020), with a relatively low investment, the annual coal consumption of approximately of 3 million tons is reduced. Significantly reduce the emission of pollutants from coal power plants of EPS can be achieved (for example, CO_2 emissions is reduced by 6% compared to the emissions of 2008). Beside contribution to environmental protection and public health protection, using of domestic solid renewable fuels other positive effects may be other socio-economic benefits such as growing jobs, development of rural areas, as well as the velocity of economic trends in country.

Finally, the existence of the stable and long-term customer which would be a buyer of significant quantity of renewable energy (it would be the Electric Power Industry of Serbia), presents unique opportunity that over various funding models, relatively quickly establish a domestic market for these fuels. Also, the prices have to be affordable to other interested users (industrial plants, coal heating plants, and so on).

Further analysis for above mentioned is necessarily. It is needed to get the appropriate strategy, and then the business decisions on state level regarding the use of solid renewable fuels with view to the production of electricity and thermal energy.

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