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ECONOMIC AND ECOLOGICAL IMPORTANCE OF SOLID BIOFUELS IN OUR COUNTRY AND WORLDWIDE

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Abstract: It is a common belief that solid biofuels represent a viable alternative to fossil fuels and climate change mitigation is acknowledged. This paper presentstypes of solid biofuels according to relevant national and international standards. The present importance has been elaborated, thus anticipated the future importance in the overall production and trade of energy in the world, the EU and in our country. Particular emphasis is placed on new trends and concepts in the production and trade of solid biofuels. Furthermore the analysis of raw material base of the Republic of Srpska (RS) and Bosnia and Herzegovina (B&H) indicated direction of its possible expansion by establishing short rotation coppices (black locust, poplar and willow) and intensive plantations of energy grasses (Chinese silver grass, giant reed, miscanthus, reed canary grass, and switchgrass). Within this topic, the presence of solid biofuels in the sectoral strategies of RS was examined. At the end, the environmental risks in case of intensification of exploitation of our forest ecosystems were specified.

Keywords: *solid biofuel production, RS, B&H*

INTRODUCTION

The oil crisis, which occurred in the 70's of the last century not only led to a dramatic jump in crude oil prices, but it also induced a number of initiatives in the most developed countries of the world to reduce the dependence of their economy to oil by using alternative energy sources.

In the nineties of the last century mankind was faced with a sudden increase of average temperature in the atmosphere and oceans, known as the global warming. The main cause of this phenomenon is based on the increased concentration of greenhouse gasses due to the excessive use of fossil fuels. Efforts to place the newly emerged situation under control were formalized through the UN Framework Convention on Climate Change (Rio, 1992) and the Kyoto Protocol (1997). At the same time the awareness of the limited reserves of fossil fuels has matured in the world. According to the US Energy Administration (EIA), crude oil reserves will be depleted in the next 50 years,

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natural gas in 65 years and coal resources in 120 years if the current level of use continues (Anon., 2013). In the same context, utilization of biomass for production of biofuels represents a realistic option for the substitution of fossil fuels with renewable fuels arising from natural resources, while reducing emissions of greenhouse gasses at the same time.For example, 20 tons of miscanthus is equivalent to 12 t of coal[2], and to 8,000 liters of heating oil (Al-Bassam, 1996). Biomass obtained from natural forest stands, energy crops and plantations is considered CO_2-neutral raw material because its combustion does not increase atmospheric CO_2 due to absorption made by crops during the growth.Energy crops and plantations protect the soil from erosion, improving content of organic matter and fertility of the land. In socio-economic terms, they contribute to the creation of new jobs and additional employment, primarily within rural population.

TYPES AND THE IMPORTANCE OF RENEWABLE ENERGY SOURCES

Until two centuries ago biofuels were the main source of energy for humans. Today they cover about 13 % of energy needs at the global level, or about 9 % when it comes to the EU-27 (tab. 1).

Table 1: Structure of energy consumption in the world and in our country in 2010(Source: Anon., 2012)

Area	Unit	Coal	Oil	Natural gas	Nuclear energy	Rene-wable energy	Other energy	Total
World	%	27,3	32,2	21,6	5,6	13	0,3	100
	Mtoe[3]	3.489,5	4.115,8	2.760,9	715,8	1.661,7	38,3	12.782
EU-27	%	15,8	36,6	24,6	13,6	9,0	0,4	100
	Mtoe	286,9	664,7	446,7	247	163,4	7,3	1.816
B&H	%					13,6		100
	Mtoe					0,9		6,4

The greatest importance among renewable energy sources in the world and the EU have biomass and wastes from renewable sources, as well as hydropower, while it is quite opposite situation is in B&H (tab. 2). About two-third of biomass energy is created in developing countries and mainly consumed for cooking and heating. One-third of this energy is generated in developed countries and it is mainly consumed for the production of electricity and heating. Geothermal, solar and wind energy in the present times are inferior to biofuels despite public opinion that renewable energy sources are based on wind turbines and solar panels. For example, the consumption of energy from renewables in the EU-27 is as follows: geothermal energy is

[2] Lewandowski et al., 1995

[3] 1Mtoe - Million Tons of Oil Equivalent 1Mtoe = 41.868 MJ = 11.630 kWh = 10.000.000 kcal

represented with 3.8 %, solar energy with 1.8 % and wind energy with 7.5 %, which means in total energy consumption that would be: 0.3 %, 0.1 % and 0.7 %, respectively. When it comes to the consumption of biomass and renewable waste in the EU-27, most represented were solid biofuels (67 %), followed by solid urban waste (13.1 %), then liquid biofuels (12.4 %) and finally biogas (7.5 %)[4].

Table 2: Structure of energy consumption from renewable resources in the world and in our country in 2010 (Source: Anon., 2012)

Area	Unit	Biomass and biomass wastes	Hydropower	Other	Total
World	%	75,4	17,7	6,9	100
	Mtoe	1.252,9	294,1	114,7	1.661,7
EU-27	%	68,6	18,5	12,9	100
	Mtoe	112,1	30,2	21,1	163,4
B&H	%	20,9	79,1	-	100
	Mtoe	0,2	0,7	-	0,9

TYPES OF SOLID BIOFUELS

Term biofuels implies that fuel is produced directly or indirectly from biomass. It can be used as it is in the form in which is produced or in forms that occur after a certain level of finishing and processing. Related to the physical state at the stage of delivery or use, different types of solid, liquid and gaseous biofuels can be identified.

Solid biofuels are used in the same form in which they are produced (for example, final shape of firewood is defined at the felling site) or after a certain processing (for example, briquette made by mechanical compression frompre-chopped biomass). Charcoal and bio-coal are types of biofuel generated by the processing. The combustion of solid biofuels produces heat and electricity. The process of simultaneous production of heat and electricity is called cogeneration. Solid biofuels can also be used as a raw material for the production of liquid and gaseous biofuels. Liquid biofuels are bioethanol and biodiesel. They are mainly used as a motor fuel and can be used to heat households or as a substitute for fuel oil. Gaseous biofuels are biogas and biomethane. They are used in the same way as natural gas.

Compared to conventional fuels, biomass based fuels are much more complex to use, primarily because of the heterogeneity of the raw material, *i.e.* species, and seasonal and regional differences. They often contain the amount of moisture which reduces their energy value, are more difficult to be put into the combustion space and they release ash and slag by combustion and corrode the firebox.

[4] Anon., 2012; Vakkilainen et al., 2013

Solid biofuels arrive to the market in many different forms, most of which are prescribed by the relevant standard. In table 3 products prescribed by the European (EN)[5] and ex-Yugoslav standards (JUS)[6] are provided.

Some products previously mentioned await the preparation of their technical specifications, like for example for forest residues and biomass bundles. Bio-coal is a new product that is not yet covered by the standard. There can be found some typical American products onthe European market - waxed briquettes and waxed wood wool firelighters.

Table 3: The existing forms of solid biofuels on the domestic and European market

Name of biofuel			Reference standards	Method of preparation
Whole tree			EN 14961-1	Without stumpwood - cross-cutting; with stumpwood - pulling, extraction
Roundwood (logs)			EN 14961-1	Delimbing, cross-cutting
Long firewood			JUS D.B5.023	Delimbing, cross-cutting
Firewood			JUS D.B5.023	Delimbing, cross-cutting splitting, stacking
Fuel wood/ firewood			EN 14961-1	Delimbing, , cross-cutting splitting, stacking
Forest residue			EN 14961-1 JUS D.B5.023	Collecting
Stump			EN 14961-1, JUS D.B5.023	Extraction, cutting, splitting
Bark			EN 14961-1 JUS D.B5.023	Debarking by hand/with machine
Bundles of biomass			EN 14961-1	Stacking the pieces lengthways, binding
Wood dust			EN 14961-1	Milling
Sawdust			EN 14961-1 JUS	Cutting with sharp tools
Wood chips			EN 14961-1 JUS D.B5.024	Cutting with sharp tools
Hog fuel			EN 14961-1	Crushing with blunt tools
Briquette			EN 14961-1	Mechanical compression
Pellet			EN 14961-1	Mechanical compression
Bale	prismatic	small	EN 14961-1	Pressing and attaching in the form of prisms
		large		

[5/] The European Committee for Standardization (CEN) governs standards with designation "EN". European standards accepted by B&H, *i.e.* Institute for Standardization of Bosnia and Herzegovina, are lebeled as "BAS EN".

[6/] JUS abbreviation used to denote Yugoslav standards from 1952 to 31.12.2005. From January the 1st 2006 instead of JUS abbreviations the abbreviation SCS - Serbian-Montenegrin standards is used. Having ceased to exist in the State union of Serbia and Montenegro, abbreviation SRPS - Serbian standards is in force. Unlike today's standards, JUS had a binding application on the whole territory of former Yugoslavia.

	cylindrical		Pressing and attaching in the form of cylinder
Chopped straw or energy grass		EN 14961-1	Chopping at harvest
Grain or seed		EN 14961-1	Without special preparation
Shell and stone fruits		EN 14961-1	Without special preparation
Exhausted olive cake		EN 14961-1	Drying
Charcoal		JUS D.B9.020	Burning with limited oxygen content

STATUS AND PROSPECTS OF SOLID BIOFUELS PRODUCTION IN THE WORLD

World trade of solid biofuels grew up by 600 % between 2000 and 2010; from 3.5 mil. tons (56.5 PJ energy equivalent) in 2000, the production increased to 18 mil. tons (300 PJ) in 2010. Europe is solid biofuels main region for international trade with two-thirds of world trade. Moreover, not all solid biofuels endure international transport due to their low density. Meanwhile this privilege belongs to wood chips, pellets, and charcoal and torrefied biomass, whereas the trade of briquette and pallet wood for fuel is accomplished by the cross-border trade exchange. Annual production of wood chips in the world is about 59.4 million tons. The largest producer is Canada with 20.7 million tons, while Europe produces around 10.6 million tons[7]. Around 19 million tons of pellets are produced annually in the world, from manufacturing plants whose capacities are significantly higher than the actual output (around 35 mil. tons). The biggest producers are Europe, Canada and the United States (Anon., 2013). There are over 600 pellet plants in the world with individual capacities above 10,000 t/yr. (Vakkilainen et al., 2013). The largest individual plant was constructed in Russia ("Vyborgskaya Cellusa") with a capacity of 900,000 t/yr.Europe is the largest market for wood pellets, mainly supplied from Canada. However, by affirming the "green politics", the US will absorb more and more pellets from Canada, leaving Europe behindhand. The main candidates to fill this gap are Indonesian plants (Ernsting, 2010). World production of charcoal is equivalent to about 1 EJ of energy. The largest producer is Brazil with 6.3 million tons or 14 % of share in total. The remaining production is predominantly related to developing countries. Torrefied biomass, unlike charcoal, is produced in developing countries. The use of torrefied biomass is mainly related to the production of pellets in order to increase their energy density and *pro rata*and to reduce transportation costs over long distances. Indicative energy capacity equivalent for torrefied wood volume in the world is around 10 PJ[8].

There are different views regarding importance of biofuels and ways to increase the volume of its production. According to EIA projections,the world energy consumption in the period 2010-2040 will increase by 56 %. Expressed in absolute units, total energy consumption will grow from 12.8 billion toe in 2010 to 15.9 billion toe in 2020 and to 20.7 billion toe by 2040. Energy made from renewables and nuclear energy will

[7] Lamers et al., 2012, 2012/1

[8]Anon., 2013

have the highest growth rates, each by 2.5 % per year. Nevertheless, fossil fuels will continue to provide almost 80 % of world energy demands by 2040. Predictions suggest that natural gas will have the highest growth rate among the fossil fuels by 1.7 % per year. Given the current policy restrictions on the use of fossil fuels, the CO_2 emissions caused by energy consumption will rise from 31 billion tons in 2010, to 36 billion tons in 2020 and up to 45 billion tons in 2040, representing a growth of 46 % in this period (Anon., 2013/1).

The EU countries and US have serious plans related to the production and use of solid biofuels and biofuels in general (liquid and gas included) in the forthcoming decades. The EU aim is to accomplish 20 % of its total energy needs from renewables by the end of 2020, primarily from biomass, while the goal of US is to replace 30 % of its oil consumption with biofuels by the end of 2030 (Perlack et Stokes, 2011). The Directives of the European Parliament and the Council of Europe on promoting renewable energy use sources was adopted in 2009. It is a part of the Energy and climate package of the EU. This Directive greatly emphasis renewable energy sources and confirms the "20-20-20"objective, which implies the increase share of renewable energy to 20 % by the end of 2020, the increase of energy efficiency by 20 % and the reduction of greenhouse gases emissions by 20 % (Anon, 2009). The "20-20-20" objectives are substantially based on biomass. Estimates suggest that it is feasible to increase the share of biomass to 120 million toe by the year 2020, with compulsory additional import of 25-40 million toe.

In order to achieve projected goals, it is necessary, *inter alia*, to:

- Make significant investments in establishment of new stands of trees and shrubs and intensive plantations of energy grasses, as well as in breeding, exploitation and transport infrastructure;
- In the forestry sector to develop a system of incentives to encourage private forest owners and contractors to be more devoted to the forest biomass;
- In the agricultural sector, provide the premium to cover the expenses of establishing short rotation crops[9] and intensive plantations of energy grasses[10] and to link periods of no income until first harvest arrive.

[9] Short rotation culture represents intensive plantations of fast-growing tree species raised on land that enable the application of mechanization, both during planting, and in the cutting phase. Under certain conditions, abandoned land is taken into consideration, followed by land on which agricultural production is not profitable, and degraded land considered for re-cultivation. These crops have high density planting, and are managed as short rotation coppice (usually up to 20 yrs.) and short production cycles (1-5 years) (Ljubojevic, 2015).

[10] Solid biofuels are produced from phytomass and herbaceous plants, such as: cereals, grasses, oilseeds, root crops, legumes and flowers. An especially interesting group is herbaceous grasses. When they are used for energy production, they are referred to as energy grasses. Perennial herbaceous grass is only once sown in multi-year growth period, at the contrary to cereals and other crops which requires seeding everyyear. In relation to the short rotation coppices, they are exploited (harvested)

According to EU projections, the largest share in supply will have the forest biomass. However, its increase is limited by natural potentials of habitats and forest management considerations. Raising a new stands of trees and shrubs and plantations of energy grasses is planned to provide almost double the growth of this biomass category, while the trend of increasing secondary resources is to be slightly slower (tab. 4). According to some analysts, the EU is not even close to satisfy its needs for biomass despite the plantations and the use of forest residues. According to Ersting (2010) competition for wood mass will escalate and the increase of wood import in the EU will be inevitable.

US Department of Agriculture (USDA) adopted in 2005 the "A billion tones" plan ("Billion Ton Report"), by which until 2030 the 30 % of oil consumption will be replaced with biofuel energy. Energy crops were selected as a major vector of increment, with three models of growth, with predicted rate of 2, 3 and 4 % per year, with implementation of "aggressive breeding programs and selection". In order to reach this goal, United States should produce one billion tons of dry lignocellulose mass each year, and thereby achieve an average yield of 19.8 t_{atro}/ha[11] (8 t_{atro}/acre)[12].

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every year and thus provide a more balanced and more frequent income (Ljubojevic, 2015).

[11] Traditional breeding and selection, as well as the introduction of genes for improved growth and tolerance to cold, have led to a significant increase in growth and adaptability and to specific site conditions in several species of poplar (*Populus* spp). Several genes for enhanced growth contributed to the volume increment in poplar for 20-40 %. With loblolly pine (*Pinus taeda* L.) a nearly twofold increment was reached by combining techniques of traditional breeding and biotechnological methods of inserting genes, together with tissue culture, also known as somatic embryogenesis. With the help of biotechnology a highly productive tropical hybrid of eucalyptus (*Eucaliptus grandis* x *E. urophylla*) was produced. The introduction of a gene that increases resistance to low temperatures enabled the expansion of its range in colder regions, without reducing yield. Dense planting and coppicing To induce the development of new shoots, plants that are planted at the end of the season or in spring next year are coppiced, *i.e.* cut above the ground. In response to this intervention, stump develops a larger number of shoots which by the height and stem increment become strong branches. Some trees have ability to develop a large number of branches (for example willow), while others have this feature less expressed (for example poplar).

Weight of biofuels with a moisture content of 0% in practice is often called atrophy weight basis in the atrophy tons (t_{atro}). Name of the suspended unit derives from the abbreviation of the German term absolut trocken - absolutely dry contribute to further improvements of yielding possibilities of this hybrid (Hinchee et al., 2009). According to Bowen et al. (2009), the global potential of energy crops in 2030 in the world is estimated at around 4 billion $t_{atro.}$

In order to satisfy the growing needs for raw materials, the practice of exploitation of whole trees, or total biomass becomes strongly present. Pioneers of the new concept are Scandinavian countries. For example, in Finland in 2010 about 1.4 million m^3 of stumps were extracted (Walmsley et Godbold, 2010); by comparison, state forestry management of RS annually produce a total of about 1.7 million m^3 of forest timber assortments (Anon., 2010). In addition to the new concepts, the practice of chipping logs, normally used to produce technical wood, can also be considered under this term.

Table 4: Projection of increase in biomass production in the EU (Source: Jeppe et al., 2011)

Sources of biomass	2010		2015		2020	
	Mtoe	%	Mtoe	%	Mtoe	%
Forestry	63,7	77,5	68,6	71,1	71,4	58,7
Agriculture	12,8	15,6	18,4	19,1	36,3	29,9
Secondary resources - waste	5,7	7,9	9,5	9,8	13,9	11,4
Total	82,2	100	96,5	100	121,6	100

NEW TRENDS AND CONCEPTS IN PRODUCTION AND TRADE OF SOLID BIOFUELS

The volume of biomass production as a raw material for biofuels can be increased in several ways, depending on its origin. When it comes to natural stands of trees and shrubs, the increase can be achieved by:

- Through introduction of new areas as a subject of exploitation;
- Increasing intervention (intensity of felling) in stands that are already in use; and
- A combination of the above mentioned ways.

In terms of artificially established stands of trees and shrubs and plantations of energy grasses, the increase can be achieved by:

- Through enlargement of area under above mentioned crops;
- Improving the individual characteristics of species, primarily their yielding potentials;
- Increasing planting density;
- Through fertilization and irrigation; and
- A combination of above mentioned ways.

Cropping and multiple land use are defined as land use on which more than one kind of product or services is implemented in one place. By combining energy crops with other functions more additional values can be achieved per unit area and thus reduce production costs.Londo (2002) provided a detailed analysis from literature and the situation on ground with several varieties of multiple land use in short rotation coppices of willow in the

Thus, 40 % of all wood pellets produced in Germany in 2009 were made from whole logs (Anon., 2010). There are cases where some large power plants are able to burn long logs, without comminution. Nevertheless, the whole trees as well as logs generally are not used as a fuel in its original form, primarily due to voluminous, however their mass can be used as a raw material for making other forms of solid biofuels, such as wood chips and hog fuel.

In densely populated regions of Western Europe, introduction of targeted production of energy crops is difficult due to existing intensive production and high prices of land.In order to overcome these problems, different strategies are developed, such as: multi-product.

[12] Perlack et Stokes, 2011

Netherlands. These solutions are not strictly specific, and can be applied in other areas as well. Use of multi-product cropping land can be realized in combination with water-protection and water-intake zones, wetlands for wastewater treatments, rehabilitation and reclamation of tailings and others. The concept of cascading chain represents a sequential exploitation of the full potential of an energy plantation/crop through multiple material applications[13].

Future prediction suggests that the demand for wood (and other forms of biomass) will continue to grow and the growth will be even stronger when the second generation of agro-fuels becomes commercially viable and economically attractive. Biotech companies, companies that produce cellulose and wood pulp as well as oil companies are joining billions of dollars for common research of agro-fuels, including genetically modified trees. Enormous efforts are being taken so that the genetic engineering of microorganisms becomes capable of producing solid biomass converted into liquid fuels without the high temperature and pressure, and then to produce genetically modified trees that can be easily converted into liquid fuel, as well as to develop new technologies based on thermal conversion. Compared to above mentioned, burning wood chips and pellets in power plants and heating plants boilers is a primitive and cheap technology.

Wood-bioenergy sector is still small compared to the pulp and paper industry, but it is almost certainly the fastest wood growing market, which will raise the price of wood around the world and thus make the short rotation coppices and the concept of industrial production and biomass utilization even more profitable. A new global market for wood energy has already been created or it will be created.

THE RAW MATERIAL BASE AND PRODUCTION OF SOLID BIOFUELS IN REPUBLIC OF SRPSKA

The Republic of Srpska has a significant forest fund. Forests and forest land in the RS occupy more than 1.3 million ha, covering about 52 % of its surface. According to the type of ownership the most common are state owned forests covering 982,468 ha (74.7 % of the area), then private forests follow with 291,877 ha (22.2 %), then national parks with 14,015 ha (1.1 %) and industrial plantations with 7,500 ha (0.6 %). Moreover, surface of so called adverse possession (earlier - the usurpation of state forests) ought not to be neglected with 17,972 ha (1.4 % of the area).

Whilst observing natural stands of trees and shrubs (which are more or less under anthropogenic influence), the most common categories are high forests with natural regeneration; their origin is generative (from seed). They occupy about 46 % of the forest land area in the state and have private ownership. After them come coppice forests; their origin is vegetative (from the stump). They occupy about 30 % of the observed surface. Shrublands and bare lands participate with about 17.6 %, while the surface unsuitable for afforestation occupy around 4.4 % and degraded forests about 2 % of the totally observed area (tab. 5).

[13] Domburg and Faaij, 2002

Table 5: Structure of natural stands of trees and shrubs in the Republic of Srpska, situation recorded on December 31st2009 (Source: Anon., 2010/1)

<table>
<tr><th colspan="6">High forests with natural regeneration (ha)</th></tr>
<tr><th>Beech</th><th>Fir and spruce; fir, spruce and beech</th><th>Scots and black pine</th><th>Sessile oak</th><th>Others</th><th>Total</th></tr>
<tr><td>205.777</td><td>230.618</td><td>38.004</td><td>68.026</td><td>16.116</td><td>558.541</td></tr>
<tr><td colspan="6">Degraded high forests (ha)</td></tr>
<tr><td>Beech</td><td>Fir and spruce; fir spruce and beech</td><td>Scots and black pine</td><td>Sessile oak</td><td>Others</td><td>Total</td></tr>
<tr><td>16.161</td><td>0</td><td>0</td><td>8.706</td><td>557</td><td>25.424</td></tr>
<tr><td colspan="6">Coppice forests (ha)</td></tr>
<tr><td>Beech</td><td>Oak</td><td>Mixed</td><td>Others</td><td colspan="2">Total</td></tr>
<tr><td>111.184</td><td>91.713</td><td>80.730</td><td>78.105</td><td colspan="2">361.732</td></tr>
<tr><td colspan="6">Surfaces suitable for afforestation (ha)</td></tr>
<tr><td colspan="2">Shrublands</td><td colspan="2">Bare lands</td><td colspan="2">Total</td></tr>
<tr><td colspan="2">97.796</td><td colspan="2">115.503</td><td colspan="2">213.299</td></tr>
<tr><td colspan="6">Surfaces unsuitable for afforestation (ha)</td></tr>
<tr><td colspan="2">Forests unsuitable for management</td><td rowspan="2">Karst and bare lands</td><td rowspan="2">Openings, communications, aisles</td><td rowspan="2">Other non-productive areas</td><td rowspan="2">Total</td></tr>
<tr><td>High forests</td><td>Coppices</td></tr>
<tr><td>12.840</td><td>11.135</td><td>24.292</td><td>3.671</td><td>1.507</td><td>53. 429</td></tr>
<tr><td colspan="6">Overall:
1.212.425</td></tr>
</table>

Coppice forests are inferior compared to high economic forests per growing stock (tab. 6) and many other features. Among other things, their life span is shorter, volume of trees at the time of cutting is lower and vitality and health condition are worse. From one hectare of coppice forests in the RS average of 0.97 m^3/ha/year of timber products are gained, while the same area of high economic forests gives 3.25 m^3/ha/yr, in other words 3.3 times more.

In a way of quality, there are three categories of coppice forests: I - coppice forests with quality stands on a favorable habitat, II - coppice forests with poor quality stands on a favorable habitat, III - coppice forests with poor quality stands on poor habitat. According to preliminary results of the Second large-scale forest inventory in B&H (Anon., 2013/2), under category I there are 6.2 % of all coppice forests in the RS (6.5 % controlled by state and 6.0 %

in the private ownership), within category II there are 34.1 % (28.9 % controlled by state and 38.5% in the private ownership) and finally under category III there are 59.7 % (64.6 % controlled by state and 55.5% in the private ownership). Compared to the average (119.3 m^3/ha), growing stock in the first quality category are higher for 1.5 times, in the second category for 1.13 times, while the third category is lower than the average in amount of 63.4 % of the main value.

Table 6: Distribution of coppice forests in the Republic of Srpska according to the type of ownership, tree species and growing stock (Source: Anon., 2010)

Type of ownership	Coppice forests according to tree species (ha)					Average growing stock (m^3/ha)	Total growing stock (m^3)
	Beech forests	Oak forests	Mixed forests	Other*)	Total		
State forests	72.185	62.362	20.802	21.965	177.314	113,7	20.160.601
Private forests	38.999	29.351	59.928	56.140	184.418	125,1	23.070.691
Total	111.184	91.713	80.730	78.105	361.732	119,3	43.231.292

**/ Willow, poplar and alder forests*

Forest plantations in the RS cover an area of about 62,000 ha. They are predominantly made of coniferous tree species. The most common are Scots and black pine, followed by spruce and fir. Deciduous plantations are located on 1,949 ha or about 3 % of total area (tab.7). Considering the fact that in our forest plantations silvicultural measures are aimed at their transformation into higher breeding form, it should not be expected they will significantly contribute to the increase of solid biofuels production.

Table 7: Representation of forest plantations in Republic of Srpska (Source: Anon., 2010)

Type of ownership	Tree species in forest plantations (ha)					
	Spruce and fir	Scots and black pine	Other coniferous trees	Sessile oak	Other deciduous tree	Total
State forests	23.548	30.692	4.714	320	1.543	60.817
Private for.	314	431	272	1	85	1.103

Within the cellulose industry "Incel" Banja Luka, in 1960 organization unit "Industrial plantations" was formed on localities of Dubrava, Kunova and Martinac with a mission to provide raw material for the factory. On the former agricultural land (which was largely orchards) culture of fast growing domestic and foreign species of conifers were established with the following relative share: eastern white pine (*Pinus strobus* L.) - 26.35 %, black pine (*Pinus nigra* Arn.) - 21,05 %, Scots pine (*Pinus silvestris* L.) 10.21 %, fir (*Picea abies*

Mill.) - 8.41 %, Japanese larch (*Larix leptolepis* Gard.) - 13.2 %, Dahurian larch (*Larix gmelini* var. *japonica* Pigl.) -10.2 % and Douglas fir (*Pseudotsuga taxifolia* Britt.) – 9 %. Over the time, the former agricultural areas have fully taken over the appearance and characteristics of high economic forests with an even-aged stand structure[14].

Forests of the Republic of Srpska annually produce about 2.2 million m^3 of various timber assortments, out of which around 0.93 million m^3 is firewood (tab. 8). If we take into consideration relative relationships that have been established at the state level , then the annual volume of felling waste is estimated in amount of 0.26 million m^3 and sawmills waste in the form of sawdust and pieces in amount of 0.41 mil. m^3. All together, the potential raw materials for the production of different solid biofuels in the RS are estimated in amount of 1.6 million m^3/year[15]. Described amounts of wood volume represent a regular (annual) production of forestry and wood processing industry. However, there should be added another 211,000 tons of wood residues arising from pruned fruit trees and about 634, 000 tons of straw that arises after the grain harvest (Anon., 2009/1).

Energy Development Strategy of the Republic of Srpska[16] among other things, point out the fact that the current consumption of biomass for combustion is 16.9 PJ, or about 92 % of the available potentials of the RS. It means without establishing new plantations for further increasing of biomass further utilization cannot be counted on without endangering the stability of forest ecosystems. Specifically, a less significant increase in the level of utilization of the natural resources can be achieved by introducing more efficient furnaces and wood boilers, which depends on certain investments (Anon., 2012/2). The Rural Development Strategic Plan of RS mapped out that strategic goal of "Nature conservation and rational management of natural resources", which defines the specific goal of "Sustainable management of rural living space" and under the implementation measures of "The production of bioenergy" (Anon., 2009/1). Forestry Development Strategy of the Republic of Srpska envisages establishment of energy plantations, fast-growing tree species plantations and short rotation coppices for the sake of biomass alimentation, with various use-value[17]. Strategy of nature protection of the RS promotes and encourages sustainable use of natural resources, reduction of pressures on biological and geological diversity as its fundamental goals (Anon., 2008).

[14] Ljubojevic et al., 2008

[15] Ljubojevic et Marceta, 2008, 2011

[16] "The Energy Development Strategy of Republic of Srpska 2030" paid insufficient attention to the production of solid biofuels. In fact, the concept of solid biofuels is not used, but instead a broader structured term "biomass" was used. Biomass as a synonym for solid biofuels received the attention of only 10 lines of text (p. 47). Also, authors missed out that the EU in 2009 adopted the "Directive 20-20-20" on the promotion and exploitation of renewable energy sources. On the other hand the strategy, after Miroslav's Gospel, is considered to be the most expensive book written in Serbian-speaking area, since its cost amounted to 680,000 BAM.

[17] Karadzic, Ljubojevic, et al., 2012

Table 8: Volume and assortment of timber production in natural forests in the RS (Source: Anon., 2010/1)

Forest category		Logs	Power poles	Pitwood and other roundwood	Pulpwood	Fuelwood	Total
		(m^3/yr)					
State forests							
High forests with natural regeneration		780.600	1.635	31.791	203.745	566.969	1.584.740
Degraded high forests		625	0	8	338	16.196	17.157
Coppice forests		9.048	77	1.032	2.662	67.602	80.421
Total	m^3/yr	790.273	1.712	32.831	206.745	650.767	1.682.328
	%	47,0	0,1	1,9	12,3	38,7	100
Private forests							
High forests		123.916	950	14.464	7.169	83.057	229.556
Coppice forests		71.140	0	6.025	5.053	190.123	272.341
Random yield		10.247	114	1.458	473	6.278	18.570
Total	m^3/yr	205.303	1.064	21.947	12.695	279.458	520.467
	%	39,4	0,2	4,2	2,4	53,8	100
Overall							
	m^3/yr	995.576	2.776	54.778	219.442	930.225	2.202.795

Coppice forests in the RS represent a potential dendromass source (tab. 6). By clearcutting the part of coppice forests made up from low quality stands on poor habitats in RS (215,954 ha) and by their direct conversion into the form of higher breeding, theoretically around 16.26 million m^3 of timber (215,954 ha x 75.64 m^3/ha) could be released on a one-time basis. Another arising question is whether such a measure would be economically viable, bearing in mind low quality and low market value of dendromass, on the one hand, and high production costs increased by the price of biological reproduction, on the other hand. Apart from the economic matter much more important is the environmental aspect. Namely, direct-conversion applies to the removal of all coppice forest trees; therefore its impact on the water regime is particularly emphasized, unless this management measure is carried out in a large area. This may lead to aquatic soil erosion, with unforeseeable consequences not only for the forest ecosystem, but also for its gravitating environment.

RESOURCE BASE AND PRODUCTION OF SOLID BIOFUELS IN BOSNIA AND HERZEGOVINA

Currently most important raw material for solid biofuel production in B&H is forest biomass, consisting of firewood, felling waste and sawmill waste. Annually in B&H about 4.4 million m^3 of timber is cut down, from

which amount about 3.7 million m^3 of different wood assortments are prepared, followed by about 2.4 million m^3 of wood for industrial purposes and pulp wood, and about 1,3 mil. m^3 of firewood[18]. After felling, inside around 0.5 million m^3 of residual wood pieces remains in the forest (tab. 9). By primary processing the wood for industrial purposes and a small portion of pulpwood, around 0.77 million m^3 of sawmill waste is produced in the form of chops and sawdust. Accordingly, B&H has each year at dispose about 2.6 million m^3 of forest dendromass as a potential raw material for the production of different solid biofuels.

Table 9: The annual amount of forest residues and wood waste in B&H (According to Anon. 2011)

The origin of wood residues	Category of wood residues	Tree species	Quantities	
			m^3/yr	t/yr
Felling waste	Residual pieces	Hardwood	295.529	212.781
		Coniferous	202.866	91.290
		Total	498.395	304.071
Sawmill waste	Sawdust	Hardwood	283.300	203.976
		Coniferous	145.227	65.352
	Chops	Hardwood	212.475	152.982
		Coniferous	145.227	65.352
		Total	766.229	485.662
Overall			1.284.624	791.733

POSSIBILITIES FOR EXPANSION OF RAW MATERIAL BASE

Apart from the natural forest stands, the RS and B&H in a whole possess a significant spatial potential for establishing short rotation coppices, primarily of black locust (*Robinia pseudoacacia*), poplar and willow, as well as intensive plantations of energy grasses, with an emphasis on Chinese silver grass (*Miscanthus sinensis*), miscanthus (*Miscanthus x giganteus*), reed canarygrass (*Phalaris arundinaceae*), switchgrass (*Panicum virgatum*), and giant reed (*Arundo donax*), (Ljubojevic, 2015). Potentially favorable surfaces for cultivation of such species are all abandoned or low quality lands, on which conventional cultivation of agricultural crops is not possible or it is not cost-effective, as well as forest lands where terrain configuration allows implementation of contemporary agricultural practices.

Potentially favorable surfaces for growing giant reed are located in the southern part of Herzegovina. Reed canarygrass in our country appears as a natural species, most frequently linked to wetlands. *Inter alia*, it was registrated in hydrophilic communities *Polygono-Bidentetum tripartitae* (W. Koch) Lohm. and*Xanthieto riparii - Chenopodietum rubri* Lohm et Waltham.

[18] Jovanovic et al., 2008

For the time being there is no data about its yield opportunities in our region, whether in the wild or as a culture. In case of foreign cultivars introduction, one should be carefully acknowledging that the largest area under reed canary grass in Europe are located in the Scandinavian and Baltic countries, in latitudes above 55 ^{o}N. Their reproduction material is adapted to low temperatures, including freezing ground and at the same time to long periods of daylight during dormancy. Additionally, the RS lacks experience in the production of miscanthus which could be directly used as a foothold in defining commercial plantations sites. Serbia has certain experiences, but only at the experimental level. A similar situation exists in Croatia as well. By available basis from literature sources, and knowledge acquired from study trips abroad as well as visual observation of the terrain, as a potential sites for the establishment of miscanthus plantations wider coastal areas of rivers belonging to the Black Sea basin can be generally recommended, and those areas where corn can be cultivated. Compared to its relatives, Chinese silver grass can be planted at higher altitudes and in drier locations. Switchgrass in comparison to the previously observed species has least requirements towards habitat; therefore its planting is encouraged even on land of lower quality, including marginal land and minesoils.

CONCLUSIONS

- The greatest significance among the renewable energy sources in the world and in the EU has biomass and wastes made from renewable sources, including hydropower, while the opposite situation is in B&H. Geothermal, solar and wind energy nowadays are inferior to biofuels despite public opinion that renewable energy sources are based on wind turbines and solar panels.

- World trade of solid biofuels is experiencing robust growth forthe last 15 years, where a major region of international trade is Europe, where 2/3 of world trade take place.

- There are different views on the importance of biofuels and ways to increase the volume of their production in the forthcoming decades. It is anticipated that energy from renewable sources and nuclear energy will have the highest growth rates. Nevertheless, fossil fuels will continue to provide almost 80 % of world energy needs by 2040, which will lead to further increase of CO_2 emissions.

- The EU and US have serious plans for the production and use of solid biofuels and biofuels in general (liquid and gas included) in the following decades. This cannot be said for RS and B&H, in whose sectoral strategies solid biofuels are marginally represented.

- The current consumption of combustion biomass in the RS reaches about 92 % of the available resources, meaning that without establishing a new plantations further increasing of biomass further utilization cannot be counted on, without endangering the stability of forest ecosystems. Direct conversion of coppice forests to the form of higher breeding, theoretically could provide in a short-term basis a significant amount of wood volume. However, a management measure of such kind could lead to aquatic soil erosion, with unforeseeable consequences not only for the forest ecosystem, but also for its gravitating environment.

PRIVREDNI I EKOLOŠKI ZNAČAJ ČVRSTIH BIOGORIVA KOD NAS I U SVIJETU

Profesor dr Srđan Ljubojević

Apstrakt: Vlada opšte uvjerenje da čvrsta biogoriva predstavljaju održivu alternativu za fosilna goriva i za ublažavanje klimatskih promjena. U radu su prikazani pojavni oblici čvrstih biogoriva prema relevantnim domaćim i međunarodnim standardima. Elaboriran je sadašnji i anticipiran njihov budući značaj u ukupnoj proizvodnji i prometu energije u svijetu, zemljama EU i kod nas. Posebno su apostrofirani novi trendovi i koncepcije u proizvodnji i prometu čvrstih biogoriva. Također je analizirana sirovinska baza RS i BiH, naznačeni pravci njezinog mogućeg proširenja zasnivanjem kultura kratkih ophodnji drveća i grmlja (bagrema, topola i vrba) i intenzivnih zasada energetskih trava (divlje proso, kineska srebrna trava, miskantus, tokavica, velika trska). U okviru ove teme, analizirana je zastupljenost čvrstih biogoriva u sektorskim strategijama RS. Na kraju je ukazano na ekološke rizike u slučaju intenziviranja eksploatacionih zahvata u našim šumskim ekosistemima.

Ključne riječi: *čvrsta biogoriva, proizvodnja, RS, BiH*

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