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# **Biomass as Potential Sustainable Development Driver – Case of Bosnia and Herzegovina**

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Additional information is available at the end of the chapter

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## **1. Introduction**

Bosnia and Herzegovina (B&H) is a country in southeastern Europe, on the western part of the Balkan Peninsula. B&H covers a total area of  $51.129 \text{ km}^2$  and it is almost landlocked, except for  $26 \text{ km}$  of Adriatic Sea coastline. Bosnia and Herzegovina is a transition country in the process of European integrations. The result of the privatization and the war situation in nineties is devastated economy which has to find a new ways for the further development. One of the results of transition process is also that major part of the industry are small and medium enterprises (SME) and that also has to be taken into consideration, because development strategies and plans has to be adapted according to this fact. This paper gives the analysis of the potential connections between renewable energy sources (RES), particularly biomass and sustainable development of the B&H's economy, taking into consideration specific political structure of the state. Problem if the sustainable development and integration of RES in that is universal, and some of the analyzed issues and findings from this material can be interested not only for the people tries to establish some activities in Bosnia and Herzegovina, but also for the people dealing with bioenergy generally. Bosnia and Herzegovina is consists from two entities: Republic of Srpska (RS), Federation of Bosnia and Herzegovina (FBiH), and third administrative unit, Brcko District (BD). Energy sector, forestry, environmental and climate changes related issues are under their jurisdiction.

## **2. Renewable energy sources in Bosnia and Herzegovina:**

Bosnia and Herzegovina have significant physical potential regarding to renewable energy sources and belongs to the list of the countries which can develop their energy sector mainly based on that. Due to that hydro, biomass, geothermal, wind and solar potential can play important role in the whole state economy in the forthcoming period.

Regarding to small hydro, some analysis says that theoretically water power of B&H amounts 99,256 GWh/year, technical water power potential of 356 small and big HPP (which may be built) amounts to 23,395 GWh/year, out of which 2,599 GWh/year is in small HPP. From that amount around 77% is in Republic of Srpska (RS) and 23% is in Federation of Bosnia and Herzegovina (FB&H).

Real potential for wind energy in B&H is still not fully estimated. Some estimations related to 16 macro-locations under investigations goes says that total estimated installed capacity can be 720 to 950 MW, which can produce 1440 to 1950 GWh, annually [4]. It is important to emphasize that the existing infrastructure offers adequate conditions for connecting possible locations to the grid, as the high- and medium-voltage network is well developed.

Theoretical potential of the solar energy in B&H amounts 74.65 PWh. Technical potential amounts 190.277,80 GWh, that is 6.2 times more than quantity of energy out of totally balance needs for the primary energy in FB&H during 2000 [4]. Despite this, the use of solar energy is insignificant and the exploitation of solar energy with flat-plate collectors is also limited.

It is difficult to estimate total B&H's physical and technical geothermal potential. All estimates are mainly based on some experimental drills and theoretical investigations, and according to that temperatures at the known locations in north and central part of the country are between 54 and 85°C. This temperature level is relatively low for electricity generation, but it is interesting for district heating systems.

### **3. Potential of biomass**

Looking from the time prospective, bioenergy interest has been greatly stimulated by the fuel price rises in the late 2000s. Bioenergy is seen as a way to protect against the rising fossil fuel prices, furthermore, biomass can act as a carbon sink and as a substitute for fossil fuels, due to that biomass is seen as one of the mechanisms mitigating climate changes.

Regarding definitions of biomass potentials, there are international practice and standards for that. Estimations can vary according to the calculation methodology and the assumptions made (e.g. land use patterns for food production, agricultural management systems, wood demand evolution, production technologies used, natural forest growth etc). In terms of biomass potentials, the following potential types are often discussed: theoretical, technical, economic, implementation potential and environmentally sustainable potential.

According to data from 1990, forests and forest land in BiH encompass an area of approximately 2,709.800 ha, which is around 53% of the territory of the country. Arable land accounts for 1,4 million ha and permanent meadows and pastures for 0,6 million ha [1,2]. Despite the fact that some 41% of the country comprises agriculture land, Bosnia and Herzegovina is relatively poor in agriculture resources, since some two thirds of the country is mountainous / hilly. Land is cultivated with various field crops, such as cereals, industrial crops, vegetables and fodder crops, represented just one quarter of the total agricultural land in 2008. On the contrary, meadows and pastures covered 49% of the agricultural land,

while a significant part of the arable fields remained fallow or uncultivated during the same year. Finally, permanent crops, such as orchards and vineyards, covered 4% of the agricultural land or 86.000 ha [5]. The structure of agricultural sector is characterized by small family farms which to a large extent produce for home consumption. Over 50% of agriculture holdings are estimated to be less than 2 ha. State firms are much larger but are either operating under severe constraints or inoperable due to the incomplete process of privatization. As far as forest land is concerned, public forest land amounts to 73% in RS and 83% in FBiH of the total forest land, while the rest is private [5].

Regarding to the country distribution of biomass potentials, field crop residues are mostly found (70%) in the Republic of Srpska, while livestock manure, mostly cow and chicken manure, in the Federation of Bosnia and Herzegovina. Forest based biomass distribution between the two entities is quite balanced.

Different types of biomass have been analyzed, taking into consideration their theoretical and technical potential:

- Forest based biomass includes fuel wood, forest residues and wood industry residues.
- Agricultural biomass includes field crops, arboricultural residues, livestock and agro-industrial residues.
- Energy crops in this work are defined as crops specifically bred and cultivated for energy production either by direct conversion to heat and electricity or by production of bio-fuels (solid, gaseous or liquid).
- Municipal solid waste (MSW) refers to waste collected by or on behalf of municipalities.

### **3.1. Forest biomass**

#### *3.1.1. Forest sector and its characteristics*

Forests represent one of the major natural resources in Bosnia and Herzegovina, due to their natural and diverse structure as well as their extensive natural regeneration. The main species found in BiH forests are mostly fir, spruce, Scotch and European pine, beech, different varieties of oak, and a less significant number of noble broadleaves along with fruit trees.

The professional development and management of the forestry sector has been dedicated to traditional systems and has recently (especially after a turbulent post-war period where forests have been neglected and misused) faced higher demands in terms of contributing more to the protection and enhancement of all forest functions, ranging from economical viability to social responsibility and environmental and ecological sustainability. Total forest area in Bosnia and Herzegovina amounts to 2,61 million ha, 1,59 ha in FBiH and 1,03 ha in RS, In BD, where there are approximately 11,000 ha of forests, of that 8,500 ha being privately owned and merely 2,500 ha within the public management system [4].

2,186.300 ha or 81% of forests and forest land is under state ownership, while private ownership consists of 523.500 ha or 19%. Most of these properties are very small in size (up

to 2ha) and vastly scattered throughout the country, with outstanding issues in ownership due to population migration.

According to Constitutional provisions, the ownership of forests lies in authority of entities (FBiH, RS) and BD, where ministries of forestry are responsible for administrative management of these areas through the public forest management enterprises. Public forest land amounts to 73% in RS and 83% in FBiH of the total forest land, while the rest is private. Standing volume of forest biomass amounts to 350m m<sup>3</sup> in Bosnia and Herzegovina, however the real figure is higher since no data were available for private forests in FBiH. Furthermore, forests net annual increment is estimated to approximately 10m m<sup>3</sup> or 3% of the total woodstock. Although annual growth seems high, annual wood increment is constrained by inadequate local forest management practices [3].

In conformity with data shown above, almost 400,000 ha (186,141 ha for FBiH and 207,719 ha for RS) have been assumed as being bare lands with a productive function and in those terms could be potentially included in reforestation programs.

The customary management system of natural regeneration that has been practiced in BiH throughout the centuries has contributed to realizing significant forest diversity in this sense.

Nevertheless, some preceding studies (mostly based on the satellite surveys within the EU CORINE program) have shown that actual forest cover size might be lower by 10-15% than previously projected.

Due to activities such as illegal logging, ore mining, construction, forest fires and others, forested areas have been shrinking rapidly; furthermore, a significant part of the forest cover has been declared as area with land-mines (numbers indicate some 10%) and has evident damages due to war activities. In addition there are extensive unresolved property disputes and illegal land acquisition which await resolution due to complex legal mechanisms and administration.

In the recent years, significant progress has been made in the area of forest certification, where three of the forest management public enterprises have undergone scrutiny of international auditing against the Forest Stewardship Council (FSC) certification, while several others are presently preparing to undergo the same procedure and promote sustainable forest management within their practices. Currently around 50% of state managed forests in BiH have been certified according to FSC Standards.

As mentioned before, forestry legal and institutional framework has been structured through two entities. In FBiH there are cantonal forest management companies, whereas in RS, the forestry management operations are led by a single public enterprise. This decentralization of forest management authority, legal framework (two separate laws on forests) and administration has led to further difficulties in establishing appropriate mechanisms for controlling forest operations, especially illegal logging and land acquisition in bordering areas [4].

### *3.1.2. Biomass potential from forestry and wood processing industry*

Bosnia and Herzegovina has abundant forests, with 46 % of the country area covered by forests. The production, harvesting and processing of timber is one of the country's oldest economic activities, and currently has major strategic importance for the country's economic development.

High forest predominates and deciduous species are the most dominant with beech (*Fagus* spp.) accounting for almost 40% of all species cover in the country. Oaks (*Quercus* spp.) contribute another 20%. Spruce and fir, located in the higher elevations and generally on the steepest terrain comprise an additional twenty percent of the forest cover in BiH. Annual allowable cut is calculated to 7,44 million m<sup>3</sup> according to an ongoing UNDP Project, while actual harvest was 5,60 million m<sup>3</sup> in 2008 [3]. From the 4,33 million m<sup>3</sup> of roundwood that were produced in 2008, 1,69 million m<sup>3</sup> were used as fuel wood (~40%), while 2,64 million m<sup>3</sup> were directed towards the wood industry (~60%). Furthermore, around 1,18 million m<sup>3</sup> of forest residues were produced at the logging sites.

The tradition of use biomass as energy source in Bosnia and Herzegovina has existed for a long time, but that use is characterized with a very low rate of utilization, mainly in rural and sub-urban areas as primary source for heating and cooking purposes in households and buildings. According to the recent findings from the total 77.19 PJ of final energy consumption in households, biomass makes 45.84 PJ. However, since energy demand and prices of fossil fuels rise rapidly other forest based biomass resources apart from fuelwood are also being considered for energy exploitation. These include forest residues and bark as well as residues/by-products arising from the processing of industrial wood.

Forest residues in BiH that can be utilized for energy production include tops, branches and stumps that are left at the logging sites. According to forest expert's estimation, forest residues that are available for energy purposes amount to 20% and 10% of the harvested volume of industrial roundwood and fuelwood respectively. However, no more than half these residues can be harvested due to difficulties in their collection [5].

Wood industries produce residues, such as chips and particles, sawdust, slabs, edgings and shavings. These residues can either be used in particleboards or pulp production or used for energy purposes in industrial boilers and for densified wood fuels production (pellets and briquettes). Bark is also included in industrial residues, since industrial wood is mainly debarked at the sawmills. However, in order to estimate the produced residues one needs to know the products output.

Wood industry production figures were not available on a regional level and therefore information on a national level from the Industrial Bulletin for FBiH and RS was used [1,2]. In 2008, almost 1 million m<sup>3</sup> sawmill products, 40.733 m<sup>3</sup> plywood and veneer sheets products and 2.428 m<sup>3</sup> particleboards were produced on a country level. Furniture and secondary wood industry products, such as doors, windows and parquets, were not included in this study's calculations, since they are given in different units (pieces, m<sup>2</sup>, etc.).



Feedstock was calculated by employing FAO conversion factors for each wood processing industry. Sawmill residues (excluding bark) were assumed to comprise 40% of sawmill feedstock, while plywood and veneer sheets industry residues were assumed to comprise 45% of feedstock. Bark was separately calculated as 7% of sawmill feedstock [5]. These factors depend on a number of assumptions with regards type and modernization level of each process, the production capacity of each industry, the tree species processed, etc. The factors were found to be in good agreement with literature values for the Western Balkans region. Furthermore, the availability of wood industry residues is restricted by various technical factors and was assumed equal on average to 80% for all types of wood industry residues with the exception of bark for which availability was assumed to be 60%.

Black liquor is a byproduct of the chemical wood pulp production process. According to the Industrial Bulletin for FBiH and RS Statistics, 32.809 t of unbleached coniferous chemical wood pulp (90% dry substance) were produced in 2008 in FBiH, which in terms of energy is equivalent to 74.476 m<sup>3</sup> of fuelwood. Moreover, 98.041 t of paper and paperboard were produced on a country level in 2008 [1,2]. Paper production is not a significant source of woody biomass in BiH, since the solid waste produced is very heterogeneous and contains non paper components, such as sand, metal, and glass, which cannot be used as a fuel [5].

Forest timber (fuel wood and forest residue) and wood waste from wood processing industry represent the major source of biomass for energy production in Bosnia and Herzegovina. Biomass residues from agricultural production have a significant energy potential in parts of northern and north-eastern Bosnia. Forests are one of the most important natural resources of Bosnia and Herzegovina. Bosnia and Herzegovina is one of the richest countries in Europe by the criteria of the forest coverage and diversity considering the total size of the State territory. The largest areas are covered by forests of broadleaf or deciduous trees, while about 10% of the country is covered by barren soils (i.e. one fifth of the forest soils). The total growing wood stocks in the forests of Bosnia and Herzegovina amount to 317,565,740 m<sup>3</sup> or 203.6 m<sup>3</sup>/ha (62% broadleaf trees and 38% conifers). The annual volume increment of forests in Bosnia and Herzegovina is 9,500,600 million m<sup>3</sup> or 6.1 m<sup>3</sup>/ha, the annual allowable level of wood cutting is 7,451,450 million m<sup>3</sup> or 4.75 m<sup>3</sup>/ha [3].

The energy potentials of the natural wood residue resources in Bosnia and Herzegovina are presented in Table 1.

The production, harvesting and processing of timber is one of the oldest economic activities in the Country, and has a strategic importance for the country's economic development. Some statistical estimations shows that the wood export value within the total Bosnia and Herzegovina export value is probably in order of 15%. It is further estimated that 15% of the total population receives its livelihood through the activities in forestry and forest industry.

			quantities	quantities	minimum inferior calorific value	energy potential
			m <sup>3</sup> /a	t/a	GJ/t	TJ/a
wood residue		broadleaf	295.529	212.781	10,28	2187
		conifers	202.866	91.290	10,28	938
sawmill wood waste	sawdust	broadleaf	283.300	203.976	10,28	2097
		conifers	145.227	65.352	10,28	672
	wood chops	broadleaf	212.475	152.982	10,28	1573
		conifers	145.227	65.352	10,28	672
Total			1.284.624	791.733		8139

**Table 1.** Quantities, types, structure and energy-related potential of wood residue in Bosnia and Herzegovina (based on an average volume of cutting in the period of 2007 – 2010.) [5].

Fuel wood is considered to have high value for local, small scale energy use, i.e. stoves, open fires and ovens. While this is clearly neither efficient nor perhaps environmentally optimal use of resource, it is nevertheless an essential, low cost resource for large numbers of rural people. From the 18,45 PJ estimated by this study, it is assumed that 20% will be available for new, efficient small scale wood fired boilers, stoves, etc. This would account for 820 GWh heat production annually.

Saw mill waste production is generally high due to a low process efficiency of sawmills: the net end product (lumber) represents an estimated 40 - 45% of the log (a well managed mill in Europe runs at up to 50% efficiency). The waste produced consists of wet sawdust, slabs, and the trimmings from cutting to length and width. Based on this ratio, waste from the primary and secondary wood processing industries would amount to approximately  $1.14 \times 10^6 \text{ m}^3$ . [6]

### 3.2. Agricultural biomass

The technical potential of straw production is limited by competing uses (e.g. animal feed and bedding), the need to leave material on the ground for nutrient replenishment etc, and is estimated to be 6,63 PJ. Moreover, this resource is highly dispersed. Modern, straw-fire power stations require a considerable scale to be financially viable. Hence, it is assumed that one third of this resource could be exploited via local small scale straw fired baled fired boilers or straw pellet boilers supplying residential properties with heat. This would account for 491 GWh of heat annually [5].

Based upon livestock data (pigs, chickens, cattle), the amount of slurries and manures produced has been estimated. This could be exploited via anaerobic digestion (AD). The Theoretical Potential is 6,50 PJ biogas production. However, it is assumed that much of this resource could not be aggregated between farming units to provide sufficient feedstock that a typical AD unit may require. It is assumed that 20% of theoretical potential could be realized, or 1,30PJ. The installed capacity would be 18 MWe and annual output would be 126 GWh of electricity. Given both the remote, rural location of AD units, it is assumed that the amount of heat used would be negligible [5].



### 3.2.1. *Agricultural sector overview*

Out of the total Bosnia and Herzegovina territory, amounting to 5,112,879 ha, FBiH takes up 2,607,579 ha, while RS takes up 2,505,300 ha. Farmland covers approximately 2,600,000 ha (around 52%) of that territory, and the remaining 2,400,000 ha are woodlands (around 48%).

Fragmentation of farmland in BiH constitutes an additional problem, 54% of property is under 2 ha in size, 13.5% is between 2 and 3 ha, 16% of property is between 3 and 5 ha, 10% of property is between 5 and 8 ha, about 3% of property is between 8 and 10 ha in size, and only 2.9% of property is over 10 ha in size [7].

The crops structure of cultivated plants and their share in the total sowing structure constitute an important segment of the BiH plant production. According to statistics, in the RS, harvest areas amounted to 443,300 ha in 1990, to 285,731 ha in 1996, and to 356,548 ha in 1997. In the period between 2000 and 2006, about 67.17% of total area in crops was sowed with cereals, and 26.66% with fodder crops. The situation in Federation of BiH is not much different as the total sowing area is considerably smaller and it amounted to about 206,000 ha in 2001, and 197,000 ha in 2006. [1,2].

It is clear that the sowing structure is not favourable as it is not satisfactory in terms of the size of areas in crops and in terms of the yield per unit area, which are very small and low, respectively [1,2].

The crop structure is very unfavorable. The production of cereals in areas of 1-3 ha cannot be economically justified and a commercial livestock production cannot be built on it.

Another issue that brings us to the analysis of the technological level of agricultural production in BiH are average yields of the most common crops (over 80% of arable land in BiH). The comparison of yields with the same yields in the neighboring countries gives a clear picture of average yields of main agricultural crops, and it clearly shows that the agricultural production in BiH is completely behind--between 1.1 and 4.4 times less productive.

Thus, in addition to the unfavorable structure of agricultural crops, average yields in BiH are very low, which fully qualifies this production as extensive, unproductive and therefore barely sustainable. However, the natural conditions for agricultural production are favourable, and for some crops they are even optimal in comparison with some of the neighboring countries.

The analysis of production of main types of livestock in BiH clearly reflects the habits of autarchic village farms orientated towards satisfying their own needs and keeping their own livestock numbers at the biological minimum on one hand and the tardiness of the state and its institutions, i.e. agricultural experts, to launch development process on the other.

Based on the data from the RS Statistical Institute, in 1999, over 17% of total land in the RS – BiH were pastures. If we add 10% of natural meadows to this, we arrive at the fact that almost one third of the total land can be used for livestock production.

There are great possibilities for a quality livestock production on the territory of BiH, but the number of heads of cattle must be increased, the structure must be changed and the stock composition must be improved.

### 3.2.2. Agriculture field crops and arboricultural residues

Two large categories of field agricultural residues can be defined: field crop residues and arboricultural residues. Field crop residuals are the residues that remain in the field after the crops are harvested. Depending upon the crop, the harvesting method and other parameters, field agricultural residues may include various plant part such as stems, branches, leaves, chaff, pits, etc. varying in composition, moisture and energy potential. Arboricultural residues are the residues that remain in the field after farming activities performed during the cultivation of perennial crops (pruning vineyards and trees).

Total quantities of residues were estimated using recent statistical data for the production area for each crop as well as specific coefficients indicating the ratio of residues production to cultivated area.

For each crop  $i$  cultivated in region  $j$ , the annual energy theoretical potential  $E_{rescrop_{i,j}}$  is calculated by SYNENERGY Project, based on the following formula [5]:

$$E_{rescrop_{i,j}} = r_i \cdot A_{i,j} \cdot H_i$$

$r_i$  country specific residue production per cultivated area [t/ha]

$A_{i,j}$  cultivated area of crop  $i$  in region  $j$  [ha]

$H_i$  country specific lower heating value of residue [GJ/t]

Data for crops production and harvested area in 2008 were obtained from the official statistical publications on the entity and state level. The coefficients used to estimate the quantities and the energy potential of agricultural field residues derived from local experts' estimations and references.

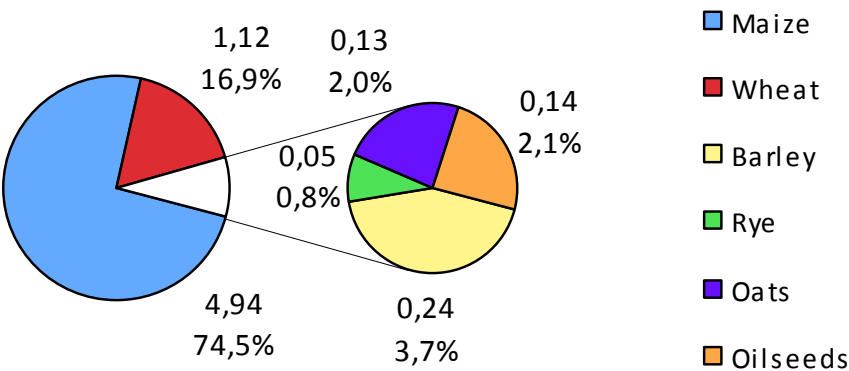
The estimation of the quantities of agricultural residues available for energy production is based on the degree of availability which is different for each crop, varies from year to year and depends on several factors such as:

- the harvesting method,
- the moisture content,
- the demand of agricultural residues for non-energy purposes (cereal straw, for example, is used for animal feeding, animal bedding, etc.),
- the need for some residues to remain on the soil to maintain the level of nutrients (sustainability reasons).

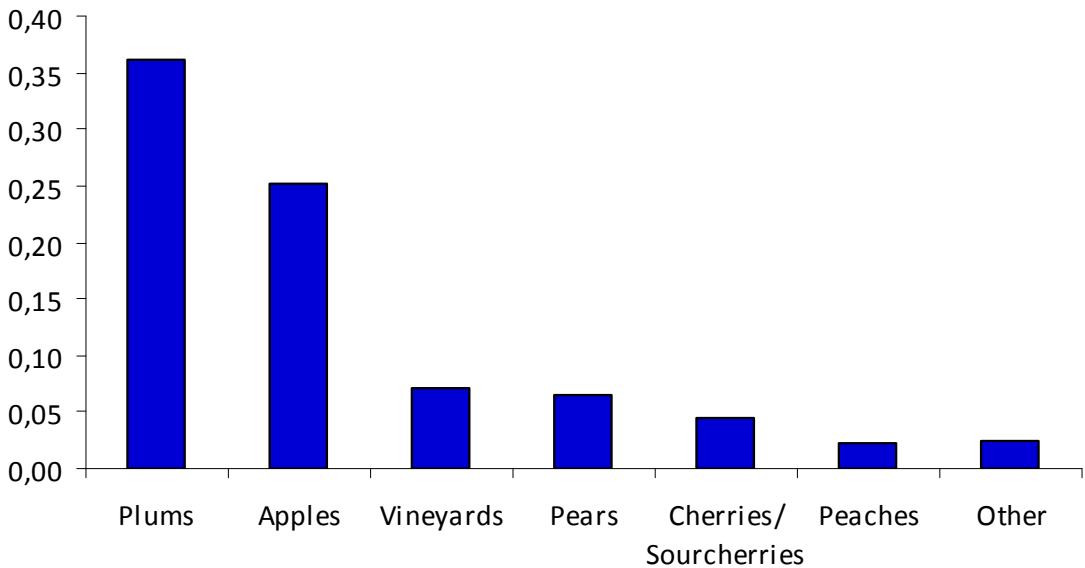
The availability factor for arable crop residues is estimated to be 30%. The same factor for arboricultural residues is estimated to be 80%, mainly due to technical difficulties in collection. Based on these factors, it is estimated that 527.765 t of field crop and

arboricultural residues could be annually exploited for energy purposes (reference year of analysis 2008). This is equivalent to 7,47 PJ or 3,24 % of the total primary energy supply in 2008, which means that crop residues could contribute significantly to the energy supply of Bosnia and Herzegovina. Almost 90% of this potential comes from field crop residues, while arboricultural residues contribute the remainder.

Figures 1 and 2 present the technical potential of the most significant crop residues. Maize residues are the most abundant source of biomass contributing 75% to the field crop residues potential or 68% to the total crop residues potential. Wheat residues share in the field crop residues potential is also significant (17%), while barley, oilseeds, rye and oats residues contribute to a lesser extent. The major part of arboricultural residues comes from plum and apple tree prunings (73%). Other sources of arboricultural residues that should be taken into account are vineyards, pears, cherries, sour cherries and peaches prunings.



**Figure 1.** Arable crop residues technical potential in Bosnia and Herzegovina in PJ [5]



**Figure 2.** Pruning's technical potential in Bosnia and Herzegovina in PJ [5].

The crop residues potential in RS is more than twice that in FBiH and Brcko district and amounts to 5,20 PJ. In RS almost 90% of the potential comes from cereals, while this

percentage is somewhat lower in FBiH (83%), where the contribution of arboricultural residues is higher (16%). Oilseed field residues have a minor contribution (1-2%) in both entities.

In the Federation of Bosnia and Herzegovina, 53% of the crop residues potential is found in the cantons of Tuzla (FBiH-K3) and Una-Sana (FBiH-K1). Another 30% of the potential is found in the cantons of Posavina (FBiH-K2) and Zenica-Doboj (FBiH-K4) as well as in the Brcko District.

### 3.2.3. Livestock manure

Energy can be derived from livestock manure as long as they are collected in lagoons or large tanks and can be considered feasible only in in-stall livestock systems, excluding therefore sheep and goats from such practices since their breeding is extensive making collection of manure impossible.

Since animal manure is of a high water content, it can be digested anaerobically for the production of biogas, which can be burnt for heat or/and electricity production.

Intensive livestock in Bosnia & Herzegovina consists of cattle, brood sows and poultry farming. According to official statistics there were 378.000 cattle (heads), 276.000 pigs and 11,26m poultry in 2008 [1,2]. The energy potential  $E_{resanim,i,j}$  for animal species  $i$  in region  $j$  was evaluated based on the formula [5]:

$$E_{resanim,i,j} = p_i C_{i,j} Y_i H_i$$

$C_{i,j}$  number of animal species  $i$  nurtured in region  $j$  [heads]

$p_i$  country specific manure generation factor for species  $i$  [t/head/yr]

$Y_i$  country specific biogas yield [Nm<sup>3</sup>/t manure]

$H_i$  country specific lower heating value of biogas [GJ/Nm<sup>3</sup>]

The manure generation factor, the biogas yield and the energy content of the produced biogas of the examined animal species depend on factors such as body size, kind of feed, physiological state (lactating, growing, etc.), and level of nutrition and coefficients regarding the residues produced on average per animal and the biogas yield per ton of produced residues were assumed according to the experts analysis in whole this region [5]. The amount of biogas that could be theoretically produced amounts to 292 million Nm<sup>3</sup>, which is equivalent to 6,50 PJ. In order to estimate the technically available livestock manure and since no further data regarding the regional distribution of animal farms that are of adequate size for biogas production were available, it was assumed that the technical potential of livestock manure would be 20% of its theoretical value, which is now the case for Croatia [5]. The available livestock manure for energy production amount to 1,30 PJ, or 0,56% of the total primary energy supply in the country in 2008 [5].

Residues from cows contribute the largest share to the total potential (50% in total), while poultry has a sizeable share (38%) and pig residues have the lowest share (12%).

Furthermore, in the same Figure it is shown that the potential is higher in the Federation of Bosnia and Herzegovina and Brcko District than in RS.

In FBiH the highest potential is found in the canton of Tuzla (FBiH-K3), which makes 40% of the total potential in FBiH and Brcko District. Furthermore, this canton exhibits the highest poultry residues potential, since 35% of the country's poultry is farmed there. Another 18% of the FBiH potential is found in the Zenica-Doboj canton (FBiH-K4) and therefore, 58% of the FBiH potential is concentrated in the north-east.

Exploitation of livestock manure for energy production via anaerobic digestion (AD) is considered to be feasible only for medium to large scale livestock units. A feasibility study called ANIWASTE financed by the EC in 2005 has sampled more than 300 farms in the wider region of Banja Luka and Lijevce polje, which is the region with the most intensive cattle raising activities. The average farm in this region has 100 pigs, 10-20 cows and 5.000-10.000 poultry. In general, the sector has passed through a post-war transition period in Bosnia and Herzegovina, which has resulted in small family farms [8].

#### 4. Energy crops

In common with other resource assessments, the potential for energy crops is, in theory, large. It is also highly dependent on which crops are deemed to be most likely to be grown, what type of land is converted to their cultivation, and the areas of land used.

The estimations were based on two reasonably scenarios [5]:

- 10% of land currently used for grazing/pasture plus 5% of fallow land are used to grow perennial grasses, and
- 10% of land currently used for grazing/pasture plus 25% of fallow land are used to grow perennial grasses.

Total available land is 95.791 ha and 147.118 ha under scenarios A and B, respectively. 72% of the available land is found in the Federation of Bosnia and Herzegovina. Then the potential of energy crop  $i$  in the region  $j$  was calculated according to the following equation [5]:

$$Enercrop_{i,j} = A_{encrj} \cdot CY_i \cdot BY_i \cdot H_i$$

$A_{encrj}$  available land in region  $j$  [ha],

$CY_i$  country specific yield of crop  $i$  [t/ha],

$BY_i$  biofuel yield of crop  $i$  [t biofuel/ t crop],

$H_i$  biofuel energy content of crop  $i$  [GJ/t].

Table 2 presents the energy crops considered in the two scenarios for Bosnia and Herzegovina, main energy markets and the energy potentials under the two scenarios.

The calculations are made for the whole land available in each case, e.g. if all the available land in Scenario A was used for biodiesel production with oilseeds the total potential would

amount to 2,12 PJ, while if it was used for second generation bioethanol from Short Rotation Coppice (SRC) it would reach 6,21 PJ. These figures summarize potentials based on conversion efficiencies. In all cases the potential in the Federation of Bosnia and Herzegovina makes 72% of the total potential.

The respective Technical Potentials are estimated to be 15,33PJ and 23,54 PJ resource. The half of the resource would support local small scale energy crop fired baled fired boilers or energy crop pellet boilers supplying residential properties with heat. This would equate to 1.703 GWh of useful heat production per year.

Crop	End use	Energy potential (PJ)	
		Scenario A	Scenario B
Oilcrops	1 <sup>st</sup> gen Biodiesel	2,12	3,26
Wheat	1 <sup>st</sup> gen Bioethanol	2,13	3,26
Maize	1 <sup>st</sup> gen Bioethanol	2,88	4,42
Perennial grasses	2 <sup>nd</sup> gen Bioethanol	7,76	11,92
	Heat & Electricity	15,33	23,54
SRC (Short Rotation Coppice)	2 <sup>nd</sup> gen Bioethanol	6,21	9,53
	Heat & Electricity	12,26	18,83

**Table 2.** Energy crops potential for biofuels (1<sup>st</sup> & 2<sup>nd</sup> generation) and bioenergy in BiH (2008) [5].

## 5. Municipal solid waste

Municipal solid waste (MSW) refers to waste collected by or on behalf of municipalities; this mainly originates from households but waste from commerce and trade, offices, institutions and small businesses is also included.

According to the EU legislation (Directive 2001/77/EC) energy produced from the biodegradable fraction of MSW is considered as renewable and therefore organic waste, waste paper and cardboard and textiles are a source of biomass. Due to lack of data regarding the share of the biodegradable part to the total quantities of MSW in BiH, the biodegradable fraction of 50% found in neighboring Serbia was employed. Furthermore, a lower heating value of 7,2 GJ/t for the biodegradable part was assumed [5].

Landfill gas. Municipal Solid Waste (MSW) production expected to reach 0,5 t/person/year (the EU 15 average). It is disposed and methane is captured and used to generate power. This assumes that, due to the location of the landfills, there are no local uses for heat. The theoretical biogas potential estimated in this study is 4,28 PJ.

In 2008, 1.367.097 t MSW was generated in Bosnia and Herzegovina, 86% of which (1.181.887 t) was collected [1,2]. This is equivalent to 308 kg of collected waste per capita per year. Other sources report a higher value of waste generation at around 500 kg/ per capita/ per year [4]. Nevertheless, it was decided to accept the number reported by the Agency for Statistics of Bosnia and Herzegovina, since it is in good agreement with waste generation rates found in other Western Balkan countries.



Table 3 shows estimated total MSW and household waste (HHW) amounts, in accordance with the methodology recommended in the SWMS , and population statistic [1,2,9].

	MSW generated in 1999 [Gg MSW]	MSW generated in 2010 [Gg MSW]	MSW generated in 2020 [Gg MSW]	MSW generated in 2030 [Gg MSW]
MSW in RS	724,269	1002,558	1347,354	1810,731
HHW in RS	362,134	501,278	673,676	905,364
MSW in FB&H	1138,0	1575,258	2117,015	2845,091
HHW in FB&H	569,0	787,629	1058,508	1422,546
Summary MSW	1862,269	2577,812	3469,369	4655,822
<b>Summary HHW</b>	931,134	1288,907	1732,183	2327,911

**Table 3.** Estimated Annual amounts of MSW and HHW at entity and country level [10].

Taking the above into account the theoretical potential of biomass from MSW can be estimated according to the following equation [5]:

$$E_{msw} = PpCoHo \text{ (F.5)}$$

P population,

p per capita waste generation [t/yr],

Co biodegradable waste fraction in MSW [%],

Ho biodegradable waste lower heating value [GJ/t].

The estimated theoretical potential amounts to 4,28 PJ or 1,9% of the country's total primary energy supply in 2008.

Currently, the main option for disposal of municipal waste is still landfilling, while most of the landfills are not sanitary. Furthermore, it is estimated that there are more than 2.000 open dumps, many located near to small municipalities in rural areas.

Implementation of SWMS commenced with WB/IDA credit for Project "Solid Waste Management Project" (Ex. Environmental Infrastructure Protection Project) in 2002. An analysis of the current situation in this sector has shown that the objectives concerning the construction of regional sanitary landfills defined in the SWSM are unrealistic. The plan is to have 16 regional landfills by December 2009, but until now, only 2 landfills have been constructed. Two regional sanitary landfills are anticipated in FBiH for 2010: "Smiljevac"-Sarajevo and "Mošćanica" - Zenica, where 10% and 8% of the total MSW collected in the FBiH would be disposed respectively. For RS, one regional sanitary landfill for MSW disposal "Ramići"-Banja Luka, is anticipated, where 16,7% of the total MSW collected in RS would be disposed. At the sanitary landfill in Sarajevo, the collected landfill gas is used for electricity generation, while at the Zenica landfill a flare system for the combustion of landfill gas has been constructed. The combustion of landfill gas by flare is also envisaged at the future sanitary landfill in Banja Luka.

In addition to landfills, according to the initial national communication of BiH under the UN framework convention on climate change (UNFCCC), incineration of 20% of MSW with energy recovery is anticipated by 2030 [4]. It is further foreseen that recycling rates will be 10% of the total household waste (HHW) in 2020 and 20% for 2030. Moreover, 50% of the recycled HHW is foreseen to be biodegradable waste.[5].

## 6. Biomass as sustainable development driver

As already mentioned above bioenergy interest has been greatly increased in last period. Thus, at present factors may influence the prospects for bioenergy:

- increases in crude oil prices,
- concerns for enhancing energy security matters, by creating de-centralized solutions for energy generation,
- concerns for climate change and global warming, but also to
- preserve non-renewable resources,
- promotion of regional development and rural diversification by creating jobs and income in usually underdeveloped rural areas,

For the developing and transition countries as Bosnia and Herzegovina, the increased deployment of modern biomass based systems, as a reliable and affordable source of energy could be part of the solution to overcoming their current constraints concerning GDP growth. In any case, production and use of biomass should be sustainable in terms of the social, environmental and economic perspectives.

Success of biomass based projects depends on the understanding of the stakeholders on the all levels which have to understand biomass resource base, its purposes and potential use in some other competitive branches, benefits and disadvantages of use of such material for energy purposes on sustainable manner. All these aspects point strongly to the importance of coordination and coherence of policies directing the supply and use of biomass for different purposes [11]. Only with policy support, established promotional mechanisms and adequate investments environment it is possible to achieve certain level of the bioenergy involvement in energy balance of certain region or country.

An appropriate political and economic strategy of the biomass utilisation for bioenergy (including biomass price policy, subsidies) within the country would evidently encourage the creation of new jobs not only in forestry, agriculture, and wood processing industry but also in other industry branches. Today, it is obviously that issue of biomass utilisation for bioenergy has political, economic and environmental dimension. Thus, governmental regulations are indispensable to provide and secure stable economic and ecologic framework conditions [3].

According to findings from the book “European Energy Payhways” (2011), there are two pathways to sustainable Energy systems in Europe [12]:

- Policy pathway,
- Market pathway.

Policy pathway takes its departure from the EU Energy and Climate Package and has a strong focus on the targeted policies that promote energy efficiency and energy from renewable energy sources (RES). The Market Pathway leaves more of the responsibility for transforming the energy systems to the market, where is cost to emit GHG is dominating policy measure.

Both pathways require significant changes in the infrastructure of the energy system and related power plants, transmission networks, fuel infrastructures, buildings and transportation systems, which is not simple, particularly for transition countries like Bosnia and Herzegovina.

Chosen policies and their applications have direct and indirect impacts on the competitiveness of bioenergy compared with other sources. It is important to increase the knowledge about the design of different tax and support regimes to get the desired effect. The implementation of bioenergy is not solely influenced by financial instruments that support the construction and operation of bioenergy plant, but also depends on policies for agriculture, forestry and the environment as well as public support.

Taking into consideration variety of biomass types coming from different sectors, as agriculture, forestry, wood processing industry, food industry, municipal waste, crucial aspect is an adequate assessment of the resources. Obtaining as much as possible accurate data about available biomass resources is demanding job because potential variations in quantities from year to year. Only theoretical estimated biomass potential for biomass resources in certain area is still not indicative data for the project development, because technical availability depends on a lot of other factors as terrain configuration, equipment selection and type. From the other side economic and market potential depends on a lot of various factors which can be transportation fuel prices, or some other market related issues.

Due to that a lot of tools have been developed in order to give accurate and clear picture about available biomass resources. Tools as GIS (Geographical Information System) are in use today in order to identify biomass resources and their availability for technical exploitation taking into consideration roads infrastructure in certain area, as well as identification of the location for biomass energy plant or some other production plants, taking into consideration access to heat or power supply networks, etc.

Achieving a secure fuel stream that satisfies the business drivers of economy, efficiency and effectiveness whilst remaining within acceptable parameters for environmental impact, quality and future sustainability will be essential to future project development.[13]

Mentzer et al. coined commonly used and well-adopted definitions of supply chains. They define the supply chain as “a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer” [13].

Sustainability of the biomass based energy projects, strongly depends on the establishment of the whole energy supply chain, from the raw material at the beginning until final product in a form of energy, synthetic fuel. Biomass is also utilized for food, feed, materials and chemicals, and bioenergy interacts with these areas; in many instances such interactions are synergistic, but they may also be in conflict.

Biomass use for bioenergy can take place immediately in the place of production or in the user's or intermediate producer's /processing firm's site. It must be economically acceptable, and it depends on the available quantities, the transport volume before and after processing, and the required technical equipment, including operation expenses. In all discussions about that, the following should be essential:

- the purpose for which the generated energy is used;
- the availability of biofuels in the close vicinity, including quantity, calorific value, processing and supply costs;
- the efficient use of that energy from biofuels, and the chances for its continuous sale to others.

On this basis, an economic model, including the selection of the equipment, has to be drawn up, and its feasibility should be verified in consideration of potential subsidies and earnings arising from selling energy to others.

The overall purpose of biomass supply chains for energy use is basically twofold: (1) Feedstock costs are to be kept competitive and (2) Continuous feedstock supply has to be ensured [14].

Future renewable energy projects will have to meet much more stringent regulations and guidelines on all areas of operations, from environmental emissions, feed stock materials, process residue disposal or recycling through to employment conditions.[13]

A significant barrier to the use of biomass in some regions is the public concern that its production is non-sustainable. In some instances, such as if harvesting native forests at a rate greater than their rate of natural regeneration, this view is clearly correct. There are simply some sources of biomass that for a variety of reasons (such as their aesthetic, recreational, biodiversity, water cycle management and carbon stock qualities) should never be used for energy purposes [14]

A key constraint to the expansion of biofuel production is the limited amount of land available to meet the needs for fuel, feed, and food in the coming decades. Large-scale biofuel production raises concerns about food versus fuel trade-offs, demands for natural resources such as water, and its potential impacts on environmental quality, biodiversity and soil erosion,.

There are also a number of economic and ecologic problems that could be solved before the economic and environmental effects will be visible in a community. The problems include:

- insufficient sensitisation of companies;

- insufficient sensitisation of the communities and their limited influence;
- insufficient knowledge of the decision-makers in the economy about the assets and opportunities that arise from biomass use for bioenergy;
- insufficient financial resources for changing the way of handling biomass resources;
- insufficient macro-economic incentives.

Biomass energy in Bosnia and Herzegovina has an important role mostly in terms of fuel wood for production of heat energy. This holds particularly true in the areas where the rural sector has a prominent role in the population structure, since historically the rural population in all areas was using the biomass for heating and/or cooking. Biomass in the form of fuel wood and charcoal is currently an ever increasing source of energy in BiH, whose average consumption is estimated at 1,323,286 m<sup>3</sup> per annum. However, the degree of efficiency of the energy conversion devices is very low. Unlike in households, biomass consumption is low in other sectors such as, for example, agriculture, trade and industry. Fuel wood is important mostly in the rural areas and small towns where no public heating network is available. In some areas of Bosnia and Herzegovina, the share of biomass in household heating reaches the level of up to 60% (parts of East Bosnia). As in many cases for development countries, the fuel security and rural development potential of bio fuels that tends to be of most interest. At this micro scale sustainable development drivers are more social-economic. Strategic approach for the rural areas has to offer new opportunities, in a sense that modern village is not only as food producer, with all difficulties related to competitiveness of its products, but also competitive energy producer, or supplier, which gives new dimension of its sustainability.

Most of the cities and rural households have its own heat supply systems, mainly low efficient boilers, which gives a chance to local producers of the biomass boilers and HVAC equipment as well as pellet and wood chips producers. This aspects will be analyzed, particularly in the context of the situation when the most large municipalities in Bosnia and Herzegovina has been signed "Covenant of Mayors" taking the real obligation for local GHG emission reduction.

There are some of district heating systems which have problem with sustainability because of low efficiency and use of expensive liquid fossil fuels. The analysis were shown that is possible to reconstruct some of them and switch the fuel to biomass, issuing lower prices of the heat produced as well as CER (Certified Emission Reduction) because such projects can be attractive as CDM.

There are a lot of small municipalities in Bosnia and Herzegovina with large physical potential of biomass and developed forestry and wood processing industry. It is easy to show that small municipalities in Bosnia and Herzegovina (with 10.000 to 20.000 inhabitants) with centralized wood processing industry can satisfy their all energy needs from its own wood waste, but also start some new business activities based on the available biomass..

Some estimations has shown that 50% of forest biomass this resource could supply medium scale CHP installations (5 MWe +) delivering power to grid and heat to residential/



commercial/ industrial users. The installed capacity would be around 21 MWe and annual output would be 149 GWh and 213 GWh of electricity and heat respectively. If half of the scenario where potential of 7,66 PJ would be available for bio-energy industry, or medium-scale CHP installations, delivering power to grid and heat to residential / commercial / industrial users, 106 MWe installed capacity that would generate 745 GWh electricity and 1.065 GWh heat annually would be supported. Technical and economy aspects of the potential use of some technologies as steam turbines, steam engines, Stirling Engines, Organic Rankine Cycle and gasification technologies in the circumstances of Bosnia and Herzegovina will be analyzed.

Modern market opportunities offers many promotional mechanisms for bioenergy based projects. Some of them which are of the high importance has been analyzed: ESCO (Energy Service Companies) and Feed-in tariffs, because they already exists in Bosnia and Herzegovina. Due to that some of the aspects related to promotional mechanisms will be analyzed.

There are no any co-firing biomass based technologies in Bosnia and Herzegovina (except of a small demonstration unit at the Mechanical Engineering Faculty of Sarajevo), but it can became interesting because some analysis shows that use of 50% of estimated forest residues would result in the production of 149 'green' GWh within existing solid fuel power facilities, which are mainly from the seventies and use low rank lignite coal.

Biomass from the wood processing industry and forestry, together with agricultural and other forms of biomass is a significant energy source and due to that deserves careful planning and estimation because it can became one of the important economy drivers.

## **6.1. Heat and electricity opportunities from biomass in Bosnia and Herzegovina**

This chapter assesses how the biomass resources - that have been identified and quantified within the previous chapters - could actually be exploited. It is obviously that the resources represent varied, sizeable and replicable opportunities for investment in modern power and heat generation technologies. Use of indigenous, renewable resources would contribute to energy-independence and give environmental benefits notably - but not only - carbon reduction.

Ways of using biomass resources include co-firing with fossil fuels; combustion in new build combined heat and power (CHP) units; anaerobic digestion; combustion at smaller scale ranging from individual stoves and ovens in households to larger, modern boilers for heat provision to buildings etc. The main options of biomass exploitation in the BiH heat, electricity and CHP market sectors are presented below. Based on the estimates on biomass technical potential the options considered for heat & electricity generation include:

### **6.1.1. Co-firing**

Total power generation capacity in BiH is around 4 GW, 2 GW of which are hydropower plants (HPP), 600 MW lignite-fired plants, and the rest coal-fired units. There are 17 district



heating (DH) systems operating in BiH. Solid fuels account for nearly 41% of total heat production [15]. It is estimated that around 180 MW<sub>th</sub> of DH systems operate with brown coal and lignite [5]

Both literature and experts opinion suggests that cofiring 5 - 10% biomass feedstock with fossil fuel (on a weight basis) require relatively minor changes to the technology that is already in place, such as fuel feed systems, storage facilities, emissions controls etc and hence relatively low capital investment. Higher proportions of biomass fuel require more profound technical issues to be addressed and therefore higher investment. Power generation and district heating plant is typically at an advanced age and is unlikely to merit substantial investment, therefore it was considered that the most likely approach would be to co-fire at lower percentages.

Waste wood, forest and industrial residues as well as agriculture residues such as prunings and straw could be used for co-firing although wood chips are the preferable fuel. Forest residues, as estimated by the study, accounts for 3,07 PJ or 380.000 tonnes. If 50% of this could be used for co-firing this would result in the production of 149 'green' GWh within existing solid fuel power facilities [5]). Coal-fired boilers in the government sector could be co-fired or fully fired on biomass fuel. It could especially be realized within government sectors (schools, health organizations etc.) in rural areas of Bosnia and Herzegovina.

#### *6.1.2. CHP generation using woody biomass*

Technical potential for forest residues reaches 3,07 PJ or 380.000 tones per year. If the remaining 50% (from the abovementioned co-firing scenario) could supply medium scale CHP installations the total installed capacity would be around 21 MWe and annual output would be 149 GWh and 213 GWh of electricity and heat respectively (SYNERGY, 2010).

#### *6.1.3. Decentralised bio-gas units*

The available livestock manure derived bio-gas can be utilized in small to medium bio-gas CHP units installed near the breeding farms. Nearly 18 MW of such installations may be fuelled by the 1,30 PJ of available bio-gas. These units could produce 126 GWh of electricity [5].

#### *6.1.4. Small scale modern heating appliances*

Currently biomass consumption comprises individual, traditional small stoves, ovens, boilers etc., with low efficiencies. The significant use of fuelwood indicates that there could be opportunities for the development of the market for modern biomass heating appliances. Over 54% of the total energy consumption in Bosnia and Herzegovina is in the household sector and 70% of this is fuel wood. Improved stoves and alternative fuels, while outside the scope of this study, are highly relevant in this context [6]).

The study estimated that if 20% of the 18,45 PJ of available fuel wood could be exploited for this purpose this would result in generating 820 GWh of heat annually [5].

#### 6.1.5. *Straw fired units*

Agricultural residues in Bosnia and Herzegovina consisting primarily of straw account for some 6,63 PJ [5]. Straw may be directly used either in decentralized small, mainly farm based units producing heat for various purposes or in centralized CHP units. Large scale central straw fired units usually require strong economies of scale (capacities in EU are around 100 MW) and are coupled with an alternative fuel, usually conventional one. Considering the significant geographical spread of straw supply and the fact that logistics play a critical role to the economics of such plants it is unrealistic to expect new straw alone fired units to be built. In this respect straw could be merely used for heating purposes either in straw bale fired units or as straw pellet in pellet stoves and boilers. If one third of the technical available straw could be directed to this use it could produce nearly 491 GWh of useful heat [5]. One potential model for utilization of some agricultural residues is in the formation of rural agricultural processing companies. The company supplies seeds, fertilizers, equipment, and training to small rural farmers, and collects harvests (including residues) for centralized, high-tech processing. Sale for process heat and electricity generation converts residues into a valuable marketable product for local and international markets (and ash potentially used for fertilizers). This business model (excluding the energy components) is currently successfully used in some developing countries [6].

#### 6.1.6. *CHP using energy crops*

The SYNENERGY study makes a reasonably conservative assumption that 10% of land currently used for grazing/pasture and 5% of the fallow land (low scenario) is used to grow perennial grasses. The Technical Potential, if perennial crops are used is estimated to be 15,33 PJ resource. It is assumed that half of this resource would be available for bio-energy industry, or medium-scale CHP installations (individual capacity 5 MWe plus) delivering power to grid and heat to residential / commercial / industrial users. This would support 106 MWe installed capacity that would generate 745 GWh electricity and 1.065 GWh heat annually [5].

#### 6.1.7. *Small scale heat with energy crops*

In the study it is estimated that the other 50% of the 15,33 PJ for energy crops would support local small scale energy crop fired baled fired boilers or energy crop pellet boilers supplying residential properties with heat. This would equate to 1.703 GWh of useful heat production per year. [5])

#### 6.1.8. *Municipal Solid Waste*

Effective treatment of municipal solid waste (MSW) represents challenge in the protection of the environment and natural resources, especially for countries in transition such as Bosnia and Herzegovina.

Cellulose or lignin derived materials, polymer based materials (plastic waste) together with inorganic material present the main components of MSW. Significant portion of plastic waste is disposed of on landfill, while only small part is recycled applying mechanical technology. Regarding the plastic waste, mechanical recycling can be recommended as a desirable technology because this makes no more pollution problems. But it is very difficult to separate various waste plastics with dust and metals into one-component raw material which can be recycled without any problems. So thermal recycle technologies are the objects of interest as alternatives for the mechanical recycle technologies. Also, the growing awareness in environmental concerns and the reducing landfill space have further prompted research in alternative methods of plastic recycling such as thermochemical conversion, particularly pyrolysis. In these technologies, pyrolysis may be favorably used for oil and monomer recovery from waste plastics. Also, this technology has more advantages than combustion technology in the view of discharging less pollutants. The resulting products of pyrolysis are solid char, liquid pyrolytic oil and gases. Each of the products formed has potential usage as energy carriers and chemical feed stocks for further processing.

Co-pyrolysis techniques have received much attention in recent years because they provide an alternative way to dispose and convert plastic polymer and cellulose (or lignin) derived materials into high value feedstock and the specific benefits of this method potentially include: the reduction of the volume of waste; the recovery of chemicals and the replacement of fossil fuels. Since MSW consist both wastes, plastic and cellulose or lignin derived materials, Co- pyrolysis techniques may be very attractive method of treating mixed MSW.

## **6.2. The possibility of using biomass in district heating systems (DHS) in Bosnia and Herzegovina as a way to achieve their sustainability**

Maybe most obvious example of unsustainable energy systems in Bosnia and Herzegovina are district heating systems, there are several reasons for that: most of them are old, built in seventies, and requires reconstructions and technical improvements, a lot of them running on expensive liquid or gaseous fossil fuels, and tariff system is more socially oriented than market oriented. There is also one important issue which makes whole concept unsustainable and requires urgent solutions, mayor shareholders of those systems are local communities, and functioning of DHS is directly affecting on their annual budgets. Due to that bioenergy can become solution for some of them, particularly with approach which consider use of clean development mechanisms of Kyoto as the one of the approaches which can make those projects sustainable.

The Clean Development Mechanism (CDM) is the one of the three flexible mechanisms (the other two are Emission Trading - ET, and Joint Implementation - JI) which allows entities from Annex I (developed) parties to develop emission-reducing projects in non-Annex I (developing) countries, and generate trade able credits – CER credits (CER - Certified

Emission Reduction, one CER is equivalent to one tonne of CO<sub>2</sub> emission reduction) corresponding to the volume of emission reductions achieved by that project.

Depending on the scale of the projects CDM projects can be classified into large-scale or small-scale projects.

There are three types of small-scale project activities; Type I: renewable energy project activities with a maximum output capacity of 15 megawatts (or an appropriate equivalent); Type II: project activities relating to improvements in energy efficiency which reduce energy consumption, on the supply and/or demand side, by up to 60 GWh hours per year (or an appropriate equivalent); Type III: other project activities that result in emission reductions of less than or equal to 60 kilotonnes of carbon dioxide equivalent annually.

Any CDM project activity not possessing the above mentioned characteristics is considered a large-scale CDM project activity.

Several options proposed under the CDM rules allow the development of CDM programmes, among them being bundles, PoAs, and several stand-alone CDM activities.

By definition, a CDM PoA is considered »a voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or stated goal (i.e. incentive schemes and voluntary programmes), which leads to GHG emission reductions or increases net GHG removals by sinks that are additional to any that would occur in the absence of the PoA, via an unlimited number of CDM programme activities (CPAs)« Bundling is a modality allowing the validation and registration of several project activities (small or large scale ones) within one CDM entry. Just like PoAs, bundles allow significant economy of scale while developing several CDM activities together.

In Bosnia and Herzegovina District Heating Systems are generally concentrated in larger cities. According to available data, currently in Bosnia and Herzegovina exists 25 District Heating Companies (12 in Republic of Srpska and 13 in Federation BiH).

District Heating Companies in Republic of Srpska mainly relies on its own boiler facilities, which mainly use fossil fuels (fuel oil, coal, gas). The exception is the District Heating Plant in Pale which as addition to coal use also biomass (waste wood) and Sokolac (only biomass). Estimated consumption of biomass in district heating sector in Republika Srpska in 2012 amounts about 1218,00 tonnes (0,1219 PJ) [16].

According to data listed in [17] the installed capacity of boilers in District Heating Companies in Republic of Srpska is 483.5 MW, the district heating sector is heated about 40 000 flats with a total area of about 2.3 million m<sup>2</sup> and about 460 000 m<sup>2</sup> of office space. According to available data, during the 2010 District heating companies in Republic of Srpska delivered to consumers about 1483 TJ of heat energy [1].

In Federation of BiH, the largest number of district heating systems also use fossil fuels (coal, fuel oil, gas). A certain number of district heating companies do not have their own thermal aggregates such as boiler units, but are connected to local heat production facilities

– thermal power plant on coal (Tuzla, Lukavac, Kakanj) or Ironworks in which is also the primary fuel coal (eg, Zenica). The largest district heating system is in Sarajevo (installed capacity of boilers is 488.694 MW and the connected heat load is about 333.162 MW) that uses mainly gas as a fuel [18].

In Federation of BiH, also two district heating systems (in Gradačac and in Livno) use biomass as primary fuel. According to available data, consumption of biomass in these two companies during the heating season 2010/11 amounted to 14 980 m<sup>3</sup> (Gračanica 12880 m<sup>3</sup>, Livno 2100 m<sup>3</sup>) and to consumers has delivered around 25.6 TJ (Gračanica 20,218 TJ, Livno 5,381 TJ) of heat energy.

According to available data, during the 2010 District heating companies in Federation of BiH delivered to consumers about 3913 TJ of heat energy [2].

One way to improve the current situation in the district heating systems which using fossil fuels is the partial or complete replacement with biomass fuels where it is possible. Those projects can be attractive as CDM project.

The analysis conducted in the District Heating Companies in Gradiška and Prijedor] which use heavy fuel oil as fuel has shown that realisation of proposed CDM Programme of Activities (PoA) would led to lower heat prices, opening of the new jobs, reduction of fossil fuels dependency of Bosnia and Herzegovina and reduction of CO<sub>2</sub> emission. In addition, by selling CERs District Heating Companies would provide additional revenues that could invest partially in the modernization of existing systems.

The District Heating Company in Gradiška provides heating for about 1740 buildings (residential buildings, public buildings such as kindergarten, schools etc. and other facilities). The vast majority of these, about 50%, are residential apartment buildings. Heated floor area in residential buildings is about 75 000 m<sup>2</sup>. It produces heat in a central boiler house, consisting of two 11.8 MW boilers with a combined capacity of 23.6 MW. The boilers are fired by heavy fuel oil, and the total connected heat load in the town is about 16.8 MW.

Average annual fuel consumption during the heating seasons (2008-2010) is about 1516 tonnes of heavy fuel oil, and heat supplied to the district heating network is about 13,35 GWh/yr. Consumption of heavy fuel oil has been increasing each year because of connection of new customers to the existing district heating network.

The District Heating Company in Gradiška intends to install a new 6 MW wood biomass boiler for production of thermal energy for heating residential and commercial facilities in Gradiška. The new biomass boiler will be installed within the existing boiler house of the company. During the heating season, the biomass boiler will provide the base heat load. In that way, the Public Communal Company "Toplana" A.D. Gradiška has estimated less consumption of heavy fuel oil (which is currently the only fuel for production of thermal energy) by approximately 1080 tonnes annually.

As part of the project, the wood biomass boiler will be connected with the existing boilers in a parallel function enabling the use of both heavy fuel oil boilers for covering peak heat load



during the coldest winter days. As a result of implementation of this project, the new installed heat capacity in production will be 29,6 MW.

Biomass fuel should be transported by a truck from the local Forestry Company or local biomass factory, about 30 km to a storage area, which will be built close to the existing boiler house. The amount of transported biomass will be supported by invoices. Calculation shows that payback period with estimated investment of 2.87 million EURO and CDM is about 6 years and 5 months.

Toplana A.D. Prijedor, the district heating company (DHC) is a main producer of heat for the town of Prijedor and it covers nearly 320 000 m<sup>2</sup> of building surface for heating. Installed heat power is 2x30 MW via two boilers. Total connected heat load in the town is about 30 MW (the second boiler is technical reserve). Annual heat energy production is approximately 50 GWh.

Today DHC uses heavy fuel oil for combustion. One of the existing boilers of 30 MW will be reconstructed in order to use wood pellets. This boiler will be the base load boiler, while the other existing boiler will be reserve and peak load boiler. The needed wood pellets will be produced by the DHC and it is a part of the project.

Production of wooden pellets includes a complete introduction of the new technological line for production of wood pellets (Figure 1). The wood pellets will have the following parameters: 6 mm diameter, 10% of moisture, 1 % of ash, and 5 kWh/kg calorific value.

The capacity of the technological line for production of wood pellets will enable production of 4 t of pellets per hour. This capacity will be sufficient for the continuous production of heat during the heating season. In addition, pellets will be produced outside the heating season and all production surpluses will be sold on the market. Raw materials used for the production are wooden sawdust, waste wood and wooden logs that are categorized as firewood. Warehouses for the reception of raw materials are located near of the boiler house and have the capacity of 20 000 m<sup>3</sup>. Energy from wood pellets will replace energy from 4901 t of heavy fuel oil. The total amount of pellets needed per heating season is about 11272 t. To produce this amount of pellets, DHC in Prijedor should provide at least 25362 m<sup>3</sup> spatial raw wood with 50 % humidity.

Calculation shows that payback period with estimated investment of 4.4 million EURO and CDM is about 5 years and 8 months, which is one year shorter than project without CDM. Reduction of CO<sub>2</sub> emission from the project will be 14 381 t/yr.

## **7. Overview of all existing barriers to harnessing the biomass energy potential**

When considering further developments in Bosnia and Herzegovina's energy sector, conventional energy wisdom has to be adapted to fit the specific context. Although hydropower will remain the mainstay of the renewable energy sector in the near future, biomass as an energy carrier does have potential on the Bosnia and Herzegovina market.



While the size of the Bosnia and Herzegovina's market place allows for some economies of scale, its capitalization, the purchasing power and even the monetization of Bosnia and Herzegovina remains low. In the rural areas, the private sector is still underdeveloped, but the human resource base is not limited, and the electricity grid is developed at a sufficient level.

Key barriers that were identified can be summarized (: the development of large-scale bioenergy plantations that can supply sustainable amounts of low-cost biomass feedstocks; the risks involved in designing, building and operating large integrated biomass conversion systems capable of producing bioenergy and biofuels at competitive prices with fossil fuels; and the development of nationwide biomass-to-bioenergy distribution systems that readily allow for consumer access and ease of use [19].

Decentralized renewable energy technologies and markets offer opportunities; but they need support, including targeted policies, capacity building, adequate financial resources to meet high up-front costs, and special effort to link-up with income generation activities. Specific barriers include [20]

### 7.1. Financial barriers

- The high capital cost of biomass energy systems is a major barrier to the increased use of these systems, despite such technologies being among the cheapest renewable energy technologies;
- The capacity to assess biomass energy proposals/loan applications is limited or non-existent;
- There are significant other priorities for public and private funds for reconstruction, food security, poverty alleviation, following the war, and local financial resources are consequently scarce;
- Since there are virtually no biomass energy projects there are no economies of scale;
- A large fraction of the energy economy (fuel wood) operates outside the formal economy;

In order to avoid financial barriers, some promotional mechanisms are usually used in realization of bioenergy projects [21]:

- **Feed-in tariffs and fixed premium;** These systems exist in various European countries (including Bosnia and Herzegovina) and are characterized by a specific premium or total price, normally set for a period of several years, that domestic producers of green electricity receive. The additional costs of these schemes are either paid by suppliers in proportion to their total sales volume and are passed through to the power consumers, charged directly to buyers of green electricity or paid by national governments using environmental taxes on conventional electricity. Fixed feed-in systems are used, for example, in Austria and Germany. Fixed-premium systems are used in Denmark, the Netherlands and Spain.

- **Green Certificate Systems;** A system of green certificate systems currently exists in five EU Member States, as well as Australia. In this case, renewable electricity is sold at conventional power-market prices, but with the right to sell government-issued certificates that guarantee the renewable character of electricity to consumers or producers that are obliged to purchase a certain number of green certificates from renewable electricity producers according to a fixed percentage, or quota, of their total electricity consumption/production. Since producers/consumers wish to buy these certificates as cheaply as possible, a secondary market of certificates develops where renewable electricity producers compete with one another to sell green certificates.
- **Tendering;** Under a tendering procedure, the state places a series of tenders for the supply of renewable electricity, which is then supplied on a contract basis at the price resulting from the tender. The additional costs generated by the purchase of renewable electricity are passed on to the end-consumer of electricity through a specific energy tax. Pure tendering procedures existed until recently in Ireland and France.
- **Investment subsidies;** In some countries, direct investment subsidies apply for biomass combustion systems. This is the case, for example, in Germany for domestic wood pellet stoves.
- **Tax deduction;** Support systems based only on tax deduction are often applied as an additional policy tool to support renewable energy. In the Netherlands for example, a company investing in a biomass combustion system may deduct an additional 44 per cent of the investment cost from their taxable income.

## 7.2. Policy barriers

- Absence of an integrated policy and regulatory framework within Bosnia and Herzegovina that would otherwise encourage the use of biomass residues for energy generation;
- Suitable policies and regulations are yet to be enacted to provide a level playing field for renewable sources, including the biomass energy;
- Policies and governmental linkages between biomass energy use and income generation activities are weak and/or non-existent;

## 7.3. Information barriers

- There is limited availability and access to existing renewable energy resource information. Data frequently does not exist, and a central information point is lacking – information is scattered between sectors; e.g. public sector, private sector (including consultancy firms), development assistance, R&D centres and academia;
- There is a limited knowledge of the biomass energy potential due to lack of detailed market surveys;
- Where information on economics, market development, marketing, and technical issues exist, it is distributed between organizations that do not co-operate;

#### 7.4. Awareness and perception barriers

- There is a lack of awareness of modern options for biomass energy. Knowledge on, for example, the competitiveness of life cycle costs of the biomass energy technologies (which can be the lowest cost option) is mostly absent.
- There is a perception that the traditional use of wood and charcoal must be reduced, so biomass energy is seen as something to be discouraged;
- There is little knowledge and no experience of the costs and benefits of the range of technologies available for modern biomass energy;
- Limited in-country capacity for renewable energy data collection and analysis is an important barrier for renewable energy project development;

#### 7.5. Institutional barriers

- Modern biomass energy services are dealt with by various ministries, agencies and institutions, on different levels, making good coordination between them a necessity if efficient use of limited human and financial resources in an area is to be achieved;
- Generally speaking, government decision-makers (who have access to and control the budget) have little interaction with those at operational level. Operational lines of communication between operation and decision-making levels need to improve within government agencies;
- Limited geographic distribution of suppliers limits access to renewable energy technologies (hardware);

#### 7.6. Technical barriers

- Bulk procurement of renewable energy technologies is limited due to the current small market for renewable energy based modern energy services. Hence the (technical) infrastructure to support renewable energy development does not exist;
- Local manufacturing and/or assembly of renewable energy technology components are currently mostly lacking;
- There is only limited technical capacity to design, install, operate, manage and maintain renewable energy based modern energy services, mainly as a result of lack of past activities in this field;
- The technical skills, including conclusive data comparing energy technologies for equivalent energy services, is limited;
- Norms and standards in terms of renewable energy performance, manufacture, installation and maintenance are weak and/or non-existing.

It is clear that without addressing the above barriers, it will be difficult to promote sustainable energy alternatives to increase biomass use in Bosnia and Herzegovina. At the same time, Governments at the entity and state level as well as the other institutions in Bosnia and Herzegovina have little capacity – financial, technical or institutional – to address these barriers [6].

## 8. Sector-wide technical assistance

In order to achieve a more significant application of biomass in BiH, first of all, it is necessary to carry out the following research:

- defining target areas in BiH where detailed research of economically and ecologically sustainable use of biomass should be performed,
- quantification of different flows of non-used biomass in target areas,
- estimation of biomass costs as a fuel in the future and a comparative analysis with the costs of other fuels,
- identification of the possibility for suitable, financially competitive solutions of biomass application,
- identification of the most suitable technologies, investment methods and incentive measures for selected solutions of biomass application,
- identification of obstacles in legislation and regulations that influence the selection of technologies for biomass application in the target areas in a most efficient way,
- identification of institutional obstacles for accepting the most efficient solutions for the construction of a biomass-fueled system for production of thermal and/or electrical energy

Implementation of the above mentioned steps would clearly show the real economical and ecological potential and solutions for the application of biomass-fueled facilities in the target areas in BiH, and it would help the competent authorities to plan the construction of such facilities. The identified activities greatly depend on the agriculture and forestry development strategy and the ministry of energy should plan and implement them together with the competent ministries for these areas [6].

Despite the high dependence of Bosnia and Herzegovina's rural population on biomass energy and the apparent large biomass energy resources, information related to the biomass energy sector is difficult to find and is frequently out of date. Modern biomass energy systems are virtually unknown, and consequently, there is a significant need for technical assistance that will benefit the sector as a whole. This should run parallel to targeted activities to develop specific biomass energy markets. Technical assistance, in the first instance, is required to deal with:

- Information on resource availability: scepticism about the availability of biomass for fuel was frequently expressed, and this manifested itself in a belief that biomass energy is something to be discouraged. Clear and unambiguous information about fuel availability (going well beyond the estimates based on production that have been used in this report) are needed;
- Awareness on options and benefits: knowledge of the options and benefits for biomass energy appears to be severely limited, and there is a need for targeted awareness raising (through, for example, study tours and training courses) and for information dissemination, including promotion campaigns and the like. This is closely tied to a need to training, human and institutional capacity building on supply, energy and heat generation, and demand.

Progress in these areas of technical assistance would provide the basis upon which further assistance could build. Assuming that a case can indeed be made for biomass energy (that sufficient bio-resources are available and cost effective technical options could be adopted), technical assistance would be required in a number of related areas including:

- Legal and contractual issues (standard biomass fuel supply contracts for example);
- Tariff adjustment, including issues related to installed capacity payments;
- Policy issues (including biomass based electricity in energy policy/plan), and the development of more coherent energy strategies for rural / remote areas;
- Government, NGO and private sector institutional requirements to support a modern biomass energy market
- Project financing and project development.

Technical assistance should go hand in hand with one or two targeted demonstration projects, characterized by relatively low risk, and with sufficient potential for the development of a viable market.

Since relevant data appears to be held by a wide variety of government, NGO and private sector stakeholders, in some cases with unhelpful competition, an institutional structure which is transparent and non-partisan is needed to make available basic and common information as envisioned through sector-wide technical assistance.

## 9. Conclusions

In contrast to many other energy technologies biomass and bioenergy production is connected to many policy areas, such as climate, energy, agriculture and waste policies, which means that definition of bioenergy policy requires more wider and inter sector approach in order to achieve sustainability of the whole system, An adequate policy concept is a key factor in the establishment of the sustainable bioenergy systems in any country. The availability and use of biomass resources are often intertwined with various major sectors of the economy: agriculture, forestry, food processing, building materials, traffic, etc, but from the other, positive side, this gives bioenergy many opportunities to generate multiple benefits apart from energy generation

It is obvious that only integral approach in establishment of biomass conversion systems, bioenergy and biofuels from biomass can find place on a market and became competitive to fossil fuels.. Bioenergy projects must be economically viable for the different actors in the value chain. Biomass used for energy purposes must be able to compete with other uses of the biomass, and at the same time the energy produced from biomass must be as cheap as or cheaper than energy produced from competing energy systems. Bosnia and Herzegovina is a country with significant potential in different biomass resources, and it is obviously that biomass and bioenergy in a forthcoming period can play more important role in the economy of the country. In order to achieve sustainable system of biomass use and exploitation, it is necessary to define an adequate policy and legal framework which leads to that goal. .

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## 10. References

- [1] Republic of Srpska Institute of Statistics  
<http://www.rzs.rs.ba/Publikacije/RSuBrojkama/RSuBrojkama2008.zip>
- [2] Federal Office of Statistics <http://www.fzs.ba/Dem/Vital/VitalnaBos.htm>
- [3] \*\*\*. Cost/Benefit Analysis in the B&H Biomass Sector – With a Special Focus on Srebrenica Region. UNDP Study, Sarajevo 2010
- [4] \*\*\*, Initial National Communication of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (UNFCCC). Banja Luka, 2009.
- [5] \*\*\*, SYNENERGY – Biomass in Bosnia and Herzegovina, Action 1: Renewable Energy Assessment, USAID HELLENIC AID ENERGY COOPERATION, CRES Greece, 2010.
- [6] Tremeer, G.B., Gvero, P., Petrovic, S., Pilot Study on Using Biomass-fired Boilers in Rural Buildings of for Rural Productive Uses Local Wood Waste in Bosnia and Herzegovina, *UNDP Study*, Bosnia and Herzegovina, 2006.
- [7] \*\*\*, National Action Environmental Plan (NEAP), 2003.
- [8] \*\*\*. ANIWASTE – Integral Solving of Waste Problem form Farms and Slaughterhouses in NW B&H Region, Feasibility Study, EU CARDS Project, 2005Kautto, N., Towards More Coherent and Sustainable Biomass Policy. Examining European Biomass-to-Energy Planning. Ph.D.Thesis, IIIIEE, Lund University, Sweden, 2011.
- [9] \*\*\*, SWMS-Solid Waste Management Strategy for BiH, EU PHARE program, AEA Technology plc, 2000.
- [10] Gvero, P.M., et.al., Renewable Energy Sources and Their Potential Role in Mitigation of Climate Changes and asa sustainable Development Driver in Bosnia and Herzegovina. *Thermal Science*. Vol.14, Issue 3 (pp.641-654), 2010.
- [11] Kautto, N., Towards More Coherent and Sustainable Biomass Policy. Examining European Biomass-to-Energy Planning. Ph.D.Thesis, IIIIEE, Lund University, Sweden, 2011
- [12] \*\*\*, European Energy Pathways, Pathways to Sustaiable European Energy Systems. Alliance for Global Sustaiability, Goteborg, Sweden, 2011.



- [13] Simpson, P. Supply chain development for biomass fuel -challenges and opportunities. IMechE Conference Transactions - Renewable Bioenergy - Technologies, Risks, Rewards, (pp.3-8), London, 2003.
- [14] Gold, S., Seuring, S., Supply Chain and Logistics Issues of Bio-nergy Production. Journal of Cleaner Production, 19 (2011) (pp.32-42).
- [15] International Energy Agency (IEA) 2010. <http://www.iea.org/stats/index.asp>,
- [16] \*\*\*, Energy balance Republic of Srpska, the plan for 2012, Government of Republic Srpska, 2012.
- [17] \*\*\*, Republika Srpska Energy Sector Development Plan until 2030. Energetski institut Hrvoje Pozar, Ekonomski institut Banja Luka, 2010
- [18] <http://www.toplane-sa.co.ba/onama.php> ,2012.
- [19] \*\*\*, Cost/benefit analysis in the B&H biomass sector – with a special focus on Srebrenica region, UNDP Study, Bosnia and Herzegovina, 2010.
- [20] Champagne, P., Biomass. Future Energy -Improved, Sustainable and Clean Options for Our Planet. In edition of Letcher, M.T., Elsevier, 2008.
- [21] Van Lo., Koppejan, J., The Handbook of Biomass Combustion and Co-firing. Earthscan, 2008.