

# Comparative Analysis of Wood Fuels Consumption in Households in the Federation of Bosnia and Herzegovina

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## ABSTRACT

Analysis of the consumption of wood energy from wood-based fuels in households in the Federation of Bosnia and Herzegovina was the main purpose of this paper. A survey on wood fuel consumption was first conducted using the Wood fuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology of the Food and Agriculture Organization (FAO) of the United Nations (UN). These results were compared to the results published by official statistics. The survey was conducted in ten cantons in the Federation of Bosnia and Herzegovina, namely in 5,475 households, 2,669 urban and 2,806 other households. The results of the research showed that wood fuels were used in 516,334 or 71.59% of the total number of households. Firewood was used in 497,139 households or in 96.28% in relation to the total number of households in the Federation of Bosnia and Herzegovina that used wood fuels. The surrounding countries showed similar trends. The estimated consumption of firewood in households using the WISDOM methodology is 4.10 (when compared to the official statistical data on total felled timber in and outside public and private forests) to 4.93 times higher than the official statistical data (when compared to the official statistical data on the sale of firewood in state forests), i.e. 4.52 times higher in average. This research indicates the need to apply a new methodological approach for the collection and analysis of data on the consumption of wood fuels in households for energy purposes. Some of the shortcomings of the existing official statistics are the neglect of statistically unregistered production of firewood from private forests and from areas not categorized as forests and forest land, as well as incomplete coverage in terms of conducting a survey on consumption of all categories of wood fuels and all major consumer categories. All the aforementioned, in addition to the economic consequences, has a negative impact on the fulfilment of commitments arising from international agreements in terms of the share of energy from renewable sources and greenhouse gas emissions in total energy consumption in Bosnia and Herzegovina. In addition, incomplete knowledge of the realistic supply and consumption of wood fuels can affect the reliability of planning documents in forestry, with many negative consequences for sustainability of a complex forest ecosystem.

**Keywords:** renewable energy sources; households; wood fuel; woody biomass; WISDOM methodology; Federation of Bosnia and Herzegovina

## INTRODUCTION

Renewable energy sources have become an inevitable topic of scientific and professional discussions regarding energy and climate change. Biomass is the most commonly used renewable energy source in the world (Toklu 2017).

Global energy trends, the growing impact of climate change and the need for energy security, make the transition to sustainable and efficient energy systems necessary due to their low greenhouse gas (GHG) emissions without (or with

minimal) negative impact on the environment (Ladani and Vinterbäck 2009, Rosillo-Calle 2016). Increased use of energy from renewable sources is an important part of the package of measures needed to reduce greenhouse gas (GHG) emissions and meet the commitments defined by the Paris Agreement on Climate Change (UNFCCC 2016). Future perspectives of the European Union indicate that the use of renewable energy shall be mostly market-oriented and, by 2030, the share of energy from renewable sources in the EU should be at least 27%. Some Member States may set more ambitious national targets (Bürgin 2015, European Commission 2015). The constant growth of energy demand at the global level has raised attention to renewable sources. Increasing the consumption of this type of energy in the EU aims to reduce dependence on fossil fuel imports, thus making energy production and consumption sustainable (Saint Akadiri et al. 2019). Woody biomass is a clean, renewable energy source that could dramatically improve our environment, economy and energy security, with significantly lower GHG emissions, reduced waste and reduced dependence on fossil fuels (Gokcol et al. 2009). According to a survey which included 11 post-transition EU countries, changes in renewable energy consumption per capita have a statistically significant impact on economic growth. Should the consumption of renewable energy increase by 1%, GDP growth is expected to be 0.68% (Faturšikić 2020). Biomass and renewable waste, with a share of 64.2% in primary renewable energy production, are the most important energy sources in the EU (Parobek et al. 2016). In order to fully exploit the potential of biomass, it is necessary to encourage greater sustainable mobilization of wood resources together with the development of new systems of sustainable forestry (European Parliament 2018).

More than a half of the felled wood globally is used as an energy source, thus supplying 9% of global primary energy production (Bailis et al. 2015). More than a fifth (21.6%) of roundwood production in the EU in 2016 was used as fuel wood (Eurostat 2018). Despite the fact that wood is the most important source of thermal energy in the Western Balkans, the sustainability of use largely depends on the improvement of existing practices, primarily related to improving the regulatory framework, finding new sources of funding and increasing commercially available biomass (Stojadinović et al. 2017). An important trend in the region is the use of significant amounts of woody biomass, with the established practice of combustion in conventional inefficient furnaces (Dunjić et al. 2016). Although some progress has been made, foreign authors have previously stated that countries such as Bosnia and Herzegovina (BiH) and Serbia have serious deficits in the promotion of renewable energy sources (RES), which lack more specific obligations in relation to the use of RES. Their growing demand for energy is mostly satisfied by fossil fuels, despite the fact that they are aware of the importance of RES, their usefulness and the need for their integration, development and use (Karakosta et al. 2012).

The Energy Community (2012a) published a study on biomass consumption in households, industry and tertiary sector in the Community member countries, using Eurostat methodology and demand-based approach determined by the survey (Robina and Lončarević 2017). The research

and data analysis within this paper were conducted using Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology, which is based on the same principles. The research using WISDOM methodology was made for all countries of the Western Balkans, namely for Slovenia for the heating season 2003/2004 (Drigo and Veselić 2006), Croatia for the heating season 2007/2008 (Segon et al. 2009), Serbia for the heating season 2009/2010 (Glavonjić 2011, Glavonjić et al. 2015), Montenegro for the heating season 2011/2012 (Marinović et al. 2013, Statistical Office of Montenegro 2013), Bosnia and Herzegovina for the heating season 2015/2016 (Glavonjić et al. 2017) and Macedonia for the heating season 2015/2016 (Trajanov et al. 2018). The research for Bosnia and Herzegovina, in addition to the above mentioned, included the consumption of certain fuels in households with the aim of improving the national energy balance (Robina and Lončarević 2017) and assessing the financial and environmental sustainability of woody biomass to replace conventional heating (Kyriakopoulos et al. 2010). Various other studies on the potentials of biomass usage were conducted in Bosnia and Herzegovina, resulting in very useful internet platforms that have been developed for some of them (e.g., <http://atlasbm.bhas.gov.ba/>) (Pfeiffer et al. 2019, Karabegović and Ponjavić 2020). The research on the consumption of energy in households, services and industry in Bosnia and Herzegovina (hereinafter abbreviated as BiH) was also conducted by the Energy Institute "Hrvoje Požar" in 2008, and the results were estimated for the national level, but also for twenty different energy consumption zones (Robina and Lončarević 2017).

Firewood, alone or in combination with other fuels, was the main energy source used for heating in households in BiH (Glavonjić et al. 2017). Out of the total number of households, 74% or 860,228 used solid fuels for heating purposes, among which 70.3% of households used only firewood, 23.2% used firewood with coal, 3.3% used firewood with other fuels. The remaining 3.2% used pellets, briquettes, wood processing residues or combined these fuels with other types of fuel. Apart from the fact that energy presents the basis of future economic and social development (Dias et al. 2004), and that biomass is the most common renewable energy source (Toklu 2017, Parobek et al. 2016), even some of the European countries and Energy Community (EC) contracting parties have no harmonized statistics on energy from biomass (Robina and Lončarević 2017). This is the reason why official data in some EU countries may be prejudiced, as indicated by a research in Greece, where empirical data indicate results and trends different from official statistics (Arabatzis and Malesios 2011). Namely, the officially published data show a decrease in the consumption of firewood due to the decreasing population in rural areas, a better life standard and the replacement of firewood with other energy sources. In contrast, empirical research indicates that, due to the economic crisis (2008) and rising oil prices, firewood consumption has increased, all indicating the importance of empirical research in collecting and presenting reliable statistics on energy consumption.

Households are an important consumer of energy from biomass, especially firewood, but these amounts of energy

have rarely been officially recorded (Robina and Lončarević 2017). This is as well confirmed by the World Bank research on biomass consumption for heating conducted for the countries of the Western Balkans (Stojadinović et al. 2017). The authors state that the use of biomass is not recorded due to the practice of statistical institutes to collect and publish data only on official trade in woody biomass. The use of wood biomass for heating in local communities located near forest areas and the use of wood by private forest owners is not recorded. This leads to the research question of whether the official statistical data represent the real consumption of biomass in BiH, primarily wood fuels. The relevance of data on actual wood fuel consumption is always limited by various variables, from a complex cross-sectoral character (forestry, agriculture, energy and rural development) to limited institutional and human resources. A complex state structure of BiH, including a large number of administrative units, further affects the complexity of collecting relevant and reliable official statistics. The application of methods that do not provide a realistic estimate of wood fuel consumption leads to incorrect conclusions, which further negatively affects the drafting of sectoral policies and decision-making on the use of wood-based energy. Further negative impact also relates to the fulfilment of current and future commitments, such as those related to the use of renewable energy sources within the Energy Community (Energy Community 2012b).

This paper is based on the results of research on the consumption of firewood and wood fuels in BiH in 2015, which was conducted from February to June 2016 within the project "Using wood energy to improve sustainable economic rural development and meet the 2020 renewable energy targets for the Western Balkans". The project was funded by the Food and Agriculture Organization (FAO) of the United Nations (UN). The aim of the research was to collect data on the types, quantities and values of wood fuels produced, imported, exported and consumed in Bosnia and Herzegovina. In addition, the research also provided data on the sources of wood fuel supply as well as on devices used for their combustion, which will be published in one of the following papers.

The paper performs a comparative analysis of the obtained results with the official statistical data for the Federation of BiH and with the data on wood fuel consumption in the surrounding countries, which indicates the (non)relevance of existing data with recommendations for improving the existing situation.

The main and auxiliary hypotheses of this paper are defined following the above, and are as follows:

- Main hypothesis: Actual consumption of firewood in households in BiH is higher than the one presented in official statistics.
- Auxiliary hypothesis 1: Consumption of firewood in households in BiH determined using the WISDOM methodology indicates similar trends to the consumption in the countries of the region.
- Auxiliary hypothesis 2: The collection and analysis of official statistics on wood fuel consumption in BiH needs to be improved to reflect the actual consumption.

## MATERIALS AND METHODS

The following scientific methods and techniques were used in this paper: content analysis and desk research (qualitative analysis of the existing literature used for theoretical framework), classification (quality data management), analysis and synthesis (detailed analysis of the available data on wood fuel consumption and their merging), deduction (determining wood fuel consumption in households based on the consumption in cantons), induction (deriving a general conclusion on the consumption based on the results for specific spatial units) and comparison (comparing the consumption within specific spatial units and comparing with official statistical data). A survey was used as an appropriate scientific research technique for field data collection.

The results on the consumption of wood fuels in the Federation of BiH presented in this paper were collected for the entire BiH within the aforementioned project by using the WISDOM methodology. WISDOM is a GIS-based methodology developed in collaboration between FAO and the Center for Ecosystems Research at UNAM University in Mexico (Sánchez-García et al. 2015). WISDOM enables the spatial representation of supply and demand for wood fuels, using data structured in three established modules, namely: SUPPLY (data related to the supply of wood fuels), DEMAND (data related to the demand/consumption of wood fuels) and INTEGRATION (related to merging and mapping of all data) (Masera et al. 2006). This enables the integration of available information regarding the supply and demand of woody biomass that can be used for energy purposes, at different administrative levels.

Data obtained by WISDOM provide strategic decision-making in the woody biomass supply and wood-based energy, including the identification of sites (in terms of effectiveness and biomass sources' availability) suitable for specific activities in order to valorise the potential of wood biomass as an energy source (Marinović et al. 2013).

This paper presents the results related to the demand module, for the Federation of BiH. Since the research was conducted within the same project for BiH (which consists of two entities - the Federation of Bosnia and Herzegovina and the Republic of Srpska), the WISDOM methodology was also used to obtain data on wood fuel consumption in the Republic of Srpska, which is presented in another scientific paper.

### Sample and Methodology for Field Survey

Basic element of the demand module development was the empirical field research of the consumption of firewood and other wood fuels through conducting the survey in the heating season 2015/2016. The research was conducted in households, commercial facilities (bakeries, shops, car services, hairdressers, hotels, shopping malls, banks, etc.), public facilities (schools, health centers and clinics) and large consumers such as woody biomass district heating systems.

Preliminary results of the 2013 census (Agency for Statistics of Bosnia and Herzegovina 2013) were used as a basis for determining a representative sample for household surveys. Due to the fact that the WISDOM methodology includes those households that use solid fuels for heating

purposes, it was necessary to conduct preliminary research and collect data on the number of households in all cantons (Federation of BiH), mesoregions (Republic of Srpska) and District Brčko which use other fuels for heating purposes, such as electricity, gas, heating oil, as well as the number of households using a district heating system.

For these purposes, the questionnaire method was used to collect data from all relevant fuel suppliers in BiH. The households that use other heating fuels/energy generating products such as electricity, gas, district heating system and oil products were excluded from the total number of households according to the census in BiH (i.e. 1,163,387 households). WISused solid fuels (wood fuels and coal) as the main heating energy source, and the sample for the survey was 1% of that number or 8,602 households.

Other authors indicate a similar number of households that use wood-based energy in BiH. Thus, the number of 869,349 households in BiH that used wood as an energy source was determined within the research conducted by the Agency for Statistics of BiH for the reference period of 12 months in 2014 (Robina and Lončarević 2017). Methodological procedures for determining the sample size for each canton, mesoregion and District Brčko were defined, along with the distribution of *urban* and *other* households. Surveys within households were conducted from 15 March 2016 to 22 April 2016 in 109 cities/municipalities throughout BiH, i.e. in the entities of the Republic of Srpska and Federation of BiH, as well as in District Brčko. A total of 8,500 households for the whole territory of BiH were surveyed, namely 3,912 households in urban settlements and 4,588 households in other settlements; 102 households less than planned were surveyed, primarily due to the lack of cooperation of respondents in some areas.

The questionnaire for households contained 22 questions, 2 of which were related to the structure of households, 11 related to the characteristics of residential buildings, 6 related to the consumption of wood fuels and 3 related to heating systems.

The survey in the Federation of BiH was conducted in 5,475 households, namely in 2,669 urban and 2,806 other households. Distribution of households by cantons is presented in Table 1.

After the conducted survey and the data entry into the web application, the entered data were checked together with the logical control of consumption. Furthermore, the data were processed, and their classification and recalculation from the sample level to the whole level were performed. The results of wood fuel consumption in households in the Federation of BiH and specific cantons are presented below.

## RESULTS

### Distribution of Households that Use Certain Types of Wood Fuels for Heating Purposes in the Federation of BiH

The obtained research results indicate that firewood and other wood fuels were used in 516,334 households at the level of the Federation of BiH. Firewood was used in 497,139 or 96.28% of the total number of households that used wood fuels, slabs from sawmills were used in 5,693 households or 1.10%, wood pellets in 12,383 households or 2.40%, wood briquettes in 264 households or 0.05%, logging residues in 751 households or 0.15%, and sawdust in 104 households or 0.02% (Figure 1).

When the consumption is observed by specific cantons in the Federation of BiH, the distribution and percentage share of households in the consumption of wood fuels is shown in Figure 2. The percentages refer to the relative share of households where firewood was used.

The above presented data indicate that firewood is the prevailing energy source, with a share of more than 95% in all cantons in the Federation of BiH, except in Canton 10, where the use of firewood was approximately 85%.

Observing the distribution of households by certain types of wood fuels, the data were as shown in Table 2. The

**Table 1.** Distribution of surveyed households by cantons in the Federation of BiH.

Canton	Total number of surveyed households	Urban households	Other households
Bosnian-Podrinje Canton	65	36	29
Herzegovina-Neretva Canton	518	239	279
Canton 10	182	57	125
Posavina Canton	103	38	65
Sarajevo Canton	1,133	990	143
Central Bosnia Canton	600	203	397
Tuzla Canton	1,153	453	700
Una-Sana Canton	601	239	362
West Herzegovina Canton	191	44	147
Zenica-Doboj Canton	929	370	559
<b>Total Federation of BiH</b>	<b>5,475</b>	<b>2,669</b>	<b>2,806</b>

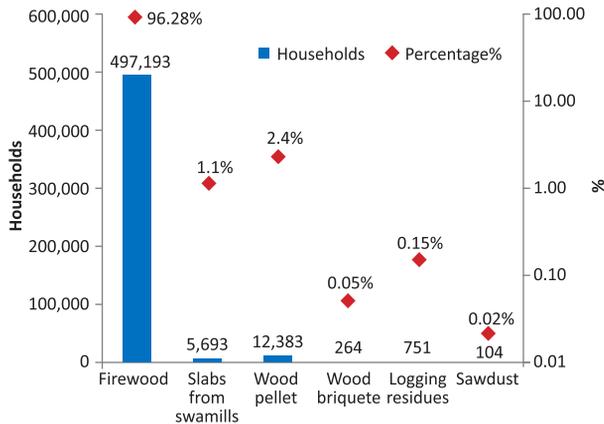


Figure 1. Distribution of households using certain types of wood fuels for heating purposes in the Federation of BiH in the heating season 2015/2016.

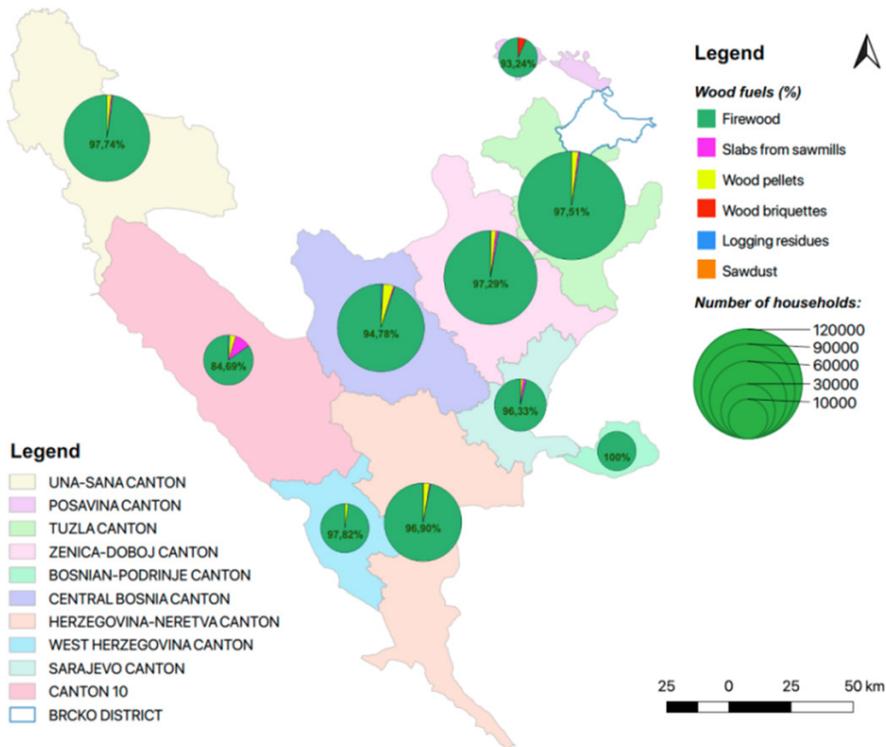


Figure 2. Distribution of households using wood fuels in each canton of the Federation of BiH in the heating season 2015/2016.

upper fields indicate the absolute amount of consumption, while the lower ones refer to the relative amount of the share of each canton in the total consumption of that fuel at the level of the Federation of BiH.

Firewood was used in 497,139 households, as follows: Tuzla Canton (114,344 or 23%), Zenica-Doboj Canton (86,212 or 17.34%), Una-Sana Canton (73,255 or 14.74%), Central

Bosnia Canton (73,156 or 14.72%), Herzegovina-Neretva Canton (59,487 or 11.97%), Sarajevo Canton (26,388 or 5.31%), West Herzegovina Canton (23,615 or 4.75%), Canton 10 (21,481 or 4.32%), Posavina Canton (11,630 or 2.34%) and Bosnia-Podrinje Canton (7,571 or 1.52%).

Slabs from sawmills were used in 5,693 households in seven cantons, predominantly in Canton 10 (2,655 or

46.64%), followed by Zenica-Doboj Canton (799 or 14.03%), Tuzla Canton (626 or 11%), Sarajevo Canton (539 or 9.47%), Una-Sana Canton (470 or 8.26%), Central Bosnia Canton (369 or 6.48%) and Herzegovina-Neretva Canton (235 or 4.13%). This type of wood fuel was not consumed in Bosnia-Podrinje Canton, Posavina Canton and West Herzegovina Canton.

Out of a total of 12,383 households that used wood pellets, the highest consumption was in households in Central Bosnia Canton (3,028 or 24.45%) and Tuzla Canton (2,291 or 18.50%), followed by households in Herzegovina-Neretva Canton (1,565 or 12.64%), Zenica-Doboj Canton (1,478 or 11.94%), Una-Sana Canton (1,222 or 9.87%), Canton 10 (997 or 8.05%), Posavina Canton (843 or 6.81%), West Herzegovina Canton (526 or 4.25%) and Sarajevo Canton (433 or 3.50%). This type of wood fuel was not consumed in households in Bosnia-Podrinje Canton.

Wood briquettes were consumed in 264 households in only three cantons, namely in Zenica-Doboj Canton (122 or 46.21%), Central Bosnia Canton (110 or 41.67%) and Sarajevo Canton (32 or 12.12%). This type of wood fuel was not consumed in households in other cantons.

Logging residues were used in 751 households, predominantly in households in Central Bosnia Canton (519 or 69.11%) and Canton 10 (232 or 30.89%), while this type of wood fuel was not consumed in households in other cantons.

Sawdust was consumed in 104 households in Herzegovina-Neretva Canton, while it was not consumed in households in other cantons.

The total number of households using wood fuels for heating in each canton in the Federation of BiH is shown in Figure 3.

### Consumption of Wood Fuels in Households at the Level of the Federation of BiH and in Each Canton

Consumption of wood fuels in households in each canton and at the level of the Federation of BiH for the heating season 2015/2016 is presented in Table 3. The upper fields indicate the absolute amount of consumption, while the lower ones refer to the relative amount of the share of each canton in the total consumption of that fuel at the level of the Federation of BiH.

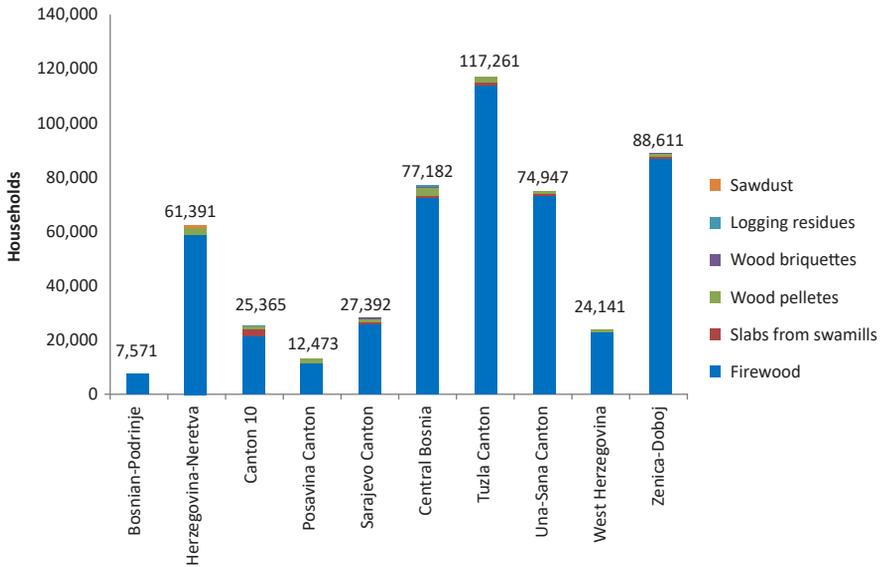
Of the total consumption of firewood, which was 2,937,340 m<sup>3</sup>, the highest consumption was in Una-Sana Canton (560,433 m<sup>3</sup> or 19.08%), Central Bosnia Canton (538,544 m<sup>3</sup> or 18.33%), Tuzla Canton (499,768 m<sup>3</sup> or 17.01%) and Zenica-Doboj Canton (494,959 m<sup>3</sup> or 16.85%), followed by Herzegovina-Neretva Canton (295,188 m<sup>3</sup> or 10.05%), Canton 10 (174,529 m<sup>3</sup> or 5.94%), Sarajevo Canton (153,472 m<sup>3</sup> or 5.22%), West Herzegovina Canton (103,259 m<sup>3</sup> or 3.52%), Posavina Canton (77,883 m<sup>3</sup> or 2.65%) and Bosnia-Podrinje Canton (39,305 m<sup>3</sup> or 1.34%).

Slabs from sawmills were consumed in a total volume of 12,339 m<sup>3</sup>, predominantly in Canton 10 (4,811 m<sup>3</sup> or 38.99%), which is further followed by Herzegovina-Neretva Canton (2,166 m<sup>3</sup> or 17.55%), Sarajevo Canton (1,653 m<sup>3</sup> or 13.40%), Una-Sana Canton (1,442 m<sup>3</sup> or 11.69%), Tuzla Canton (1,022 m<sup>3</sup> or 8.28%), Central Bosnia Canton (689 m<sup>3</sup> or 5.58%) and Zenica-Doboj Canton (556 m<sup>3</sup> or 4.51%).

The total consumption of wood pellets was 55,566 tonnes, of which almost a third was consumed in Central Bosnia Canton (16,299 t or 29.33%), followed by Tuzla Canton (9,422 t or 16.96%), Zenica-Doboj Canton (7,751 t or 13.95%), Canton 10 (5,564 t or 10.01%), Herzegovina-Neretva Canton (4,689 t or 8.44%), Una-Sana Canton

**Table 2.** Distribution of households using wood fuels in each canton in the Federation of BiH in the heating season 2015/2016, by certain types of wood fuels (Source: FAO project "Using wood energy to improve sustainable economic rural development and meet the 2020 renewable energy targets for the Western Balkans").

Wood fuel	Bosnian-Podrinje Canton	Herzegovina-Neretva Canton	Canton 10	Posavina Canton	Sarajevo Canton	Central-Bosnia Canton	Tuzla Canton	Una-Sana Canton	West Herzegovina Canton	Zenica-Doboj Canton	TOTAL Federation of BiH
Firewood	7,571 1.52%	59,487 11.97%	21,481 4.32%	11,630 2.34%	26,388 5.31%	73,156 14.72%	114,344 23.00%	73,255 14.74%	23,615 4.75%	86,212 17.34%	497,139 100.00%
Slabs from sawmills	0 0.00%	235 4.13%	2,655 46.64%	0 0.00%	539 9.47%	369 6.48%	626 11.00%	470 8.26%	0 0.00%	799 14.03%	5,693 100.00%
Wood pellets	0 0.00%	1,565 12.64%	997 8.05%	843 6.81%	433 3.50%	3,028 24.45%	2,291 18.50%	1,222 9.87%	526 4.25%	1,478 11.94%	12,383 100.00%
Wood briquettes	0 0.00%	0 0.00%	0 0.00%	0 0.00%	32 12.12%	110 41.67%	0 0.00%	0 0.00%	0 0.00%	122 46.21%	264 100.00%
Logging residues	0 0.00%	0 0.00%	232 30.89%	0 0.00%	0 0.00%	519 69.11%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	751 100.00%
Sawdust	0 0.00%	104 100.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	104 100.00%



**Figure 3.** Total number of households using wood fuels for heating in each canton in the Federation of BiH in the heating season 2015/2016.

**Table 3.** Consumption and relative share of some cantons in the total consumption of wood fuels in households in the Federation of BiH in 2015/2016.

Canton	Firewood (m <sup>3</sup> )	Slabs from sawmills (m <sup>3</sup> )	Wood pellets (tonnes)	Wood briquettes (tonnes)	Logging residues (m <sup>3</sup> )	Sawdust (m <sup>3</sup> )
Bosnian-Podrinje	39,305 1.34%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%
Herzegovina-Neretva	295,188 10.06%	2,166 17.55%	4,689 8.44%	0 0.00%	0 0.00%	11 100.00%
Canton 10	174,529 5.94%	4,811 38.99%	5,564 10.01%	0 0.00%	121 4.27%	0 0.00%
Posavina	77,883 2.65%	0 0.00%	4,107 7.39%	0 0.00%	0 0.00%	0 0.00%
Sarajevo	153,472 5.22%	1,653 13.40%	1,448 2.61%	95 20.79%	0 0.00%	0 0.00%
Central-Bosnia	538,544 18.33%	689 5.58%	16,299 29.33%	220 48.14%	2,713 95.73%	0 0.00%
Tuzla	499,768 17.01%	1,022 8.28%	9,422 16.96%	0 0.00%	0 0.00%	0 0.00%
Una-Sana	560,433 19.08%	1,442 11.69%	4,448 8.00%	0 0.00%	0 0.00%	0 0.00%
West Herzegovina	103,259 3.52%	0 0.00%	1,838 3.31%	0 0.00%	0 0.00%	0 0.00%
Zenica-Doboj	494,959 16.85%	556 4.51%	7,751 13.95%	142 31.07%	0 0.00%	0 0.00%
<b>Total Federation of BiH</b>	<b>2,937,340</b> <b>100%</b>	<b>12,339</b> <b>100%</b>	<b>55,566</b> <b>100%</b>	<b>457</b> <b>100%</b>	<b>2,834</b> <b>100%</b>	<b>11</b> <b>100%</b>

(4,448 t or 8%), Posavina Canton (4,107 t or 7.39%), West Herzegovina Canton (1,838 t or 3.31%) and Sarajevo Canton (1,448 t or 2.61%).

Wood briquettes were consumed in the total amount of 457 tonnes in the Federation of BiH, with the highest consumption in Central Bosnia (220 t or 48.14%), followed by Zenica-Doboj Canton (142 t or 31.07%) and Sarajevo Canton (95 t or 20.79%).

Logging residues were consumed in the total amount of 2,384 m<sup>3</sup> in only two cantons the Federation of BiH, namely in Central Bosnia Canton (2,713 or 95.73%) and Canton 10 (121 or 4.27%).

Sawdust was used as an energy source only in Herzegovina-Neretva Canton, in the amount of 11 tonnes.

## DISCUSSION

Firewood is the most common wood fuel in all cantons in the Federation of BiH and was used in more than 96% of households that use wood fuels. The remaining 4% of households used other types of wood fuels. The total consumption of firewood in households of all cantons of the Federation of BiH was 2.94 million m<sup>3</sup>. The highest consumption was in the following cantons: Una-Sana, Central Bosnia, Tuzla and Zenica-Doboj, which cover more than 71% or approximately 2.1 million m<sup>3</sup>. The consumption of this type of wood fuel shall be discussed more thoroughly in the second part of this chapter.

Approximately 82% slabs from sawmills were used during the heating season 2015/2016 in households in Canton 10, Herzegovina-Neretva Canton, Sarajevo Canton and Una-Sana Canton, in the total amount of more than 10 thousand m<sup>3</sup>. Total consumption of this type of wood fuel in the Federation of BiH was 12.34 thousand m<sup>3</sup>. Relatively low consumption in households can be explained by the fact that slabs are used as an energy source at the place of their origin (in wood-processing plants), as well as a raw material for obtaining more attractive wood fuels, primarily wood pellets.

Total consumption of wood pellets in households in the Federation of BiH during the heating season 2015/2016 was 55.6 thousand tonnes, with more than 60% being used in the Central Bosnia, Tuzla and Zenica-Doboj cantons. Even greater share of wood fuels in the total consumption is expected in the future, due to all the advantages related to simplicity, comfort in use and the advancement of combustion technology, as well as the advantages in the supply and use of this energy source, in addition to lower heating prices compared to some other energy sources (Thomson and Liddell 2015). However, neutral impact on the environment in the future may become one of the key factors for the selection of this type of fuel for heating, not only for environmental but also for economic reasons (for example, in case of limitation or introduction of a tax on greenhouse gas emissions or increased subsidies to meet commitments for the participation of renewable energy sources). The EU experiences show that, along with the assumption of commitments for the participation of renewable energy sources, the consumption of wood pellets has increased (Flinkman et al. 2018). On the other hand,

relatively high initial investments in equipment, pellet prices volatility, supply uncertainty, lack of subsidies and favorable credit lines for the procurement of equipment, as well as insufficient environmental education of the population, can be serious barriers to more intensive use in BiH households. Econometric models based on research conducted for seven EU countries indicate that GDP is less important, while the prices of wood pellets and alternative energy sources are of great importance for the use of wood pellets (Flinkman et al. 2018). Consumption will certainly be affected by market categories such as production, import and export. Official FAO statistics data (FAO 2021) indicate that the production of pellets in BiH increased from 83,000 tonnes in 2012 to 270,000 tonnes in 2016, which is followed by a declining trend to 230,000 tonnes in 2019. Imported quantities within the same period were significantly lower and ranged to a maximum of 14,240 tonnes in 2017. However, data on significant exports of this wood fuel, which had an upward trend in the period 2012-2014 (from 73,000 to 172,000 tonnes), followed by the declining trend between 2015 and 2019 (from 137,350 to 69,900 tonnes), indicate potential problems in available quantities in the future. The fact is that the difference in profits made in the domestic and foreign markets will play a significant role in creating the preconditions for increased consumption of this wood fuel in the entire BiH.

Wood briquettes were significantly less used compared to wood pellets. Total amount of 457 tonnes was used in only three cantons, almost half being used in Central Bosnia Canton. This wood fuel was used in Zenica-Doboj and Sarajevo cantons as well. Two main reasons caused a low consumption of briquettes, as compared to pellets. Significant quantities of briquettes produced in BiH are exported. In addition, since wood pellets represent a more comfortable fuel that burns in furnaces and boilers with automatic control, a large number of households decided to use this type of wood fuel instead of briquettes, coal and firewood. This does not mean that briquettes will no longer be used in households, but the assumptions are that consumption will have a declining trend since pellets, as a wood fuel, are easier to use.

Total consumption of logging residues was 2.8 thousand m<sup>3</sup>, namely in only two cantons, of which predominantly in Central Bosnia Canton (more than 95% of the total consumption). This can be related to different approaches in some cantons in terms of enabling the local population to collect logging residues (so-called *collection*). In addition, this represents quite a difficult way to provide heating products, which can be a limiting factor due to the lack of labor in countryside, which is caused by the departure of young people to cities and migration outside BiH. Finally, almost all forestry companies in BiH are FSC certified, and therefore obliged to leave some logging residues in forests as organic matter necessary for soil fertilization, thus ensuring the stability of soil regime.

Sawdust was even less present as an energy source, with the total amount of 11 tonnes used only in Herzegovina-Neretva Canton. The reason for such low consumption is understandable, since sawdust is used as a raw material for obtaining wood pellets and briquette.

Since the official statistics for the Federation of BiH provide data for firewood, discussion shall primarily be focused on firewood consumption, given the fact that it is the most common energy source in households (more than 96%). Data on firewood consumption in each canton in the Federation of BiH, obtained within this research, are presented in Figure 4.

Analyzing the available data issued by the Institute for Statistics of the Federation of BiH, the only data on firewood quantities in 2015 were identified in the Statistical Bulletin 226 (Institute for Statistics of the Federation of BiH 2016). This includes data on sales of firewood originating from state forests, which amounted to 653,450 m<sup>3</sup> in 2015.

Research by Glavonjić and Čomić (2016) indicates that 91.48% of firewood in the Federation of BiH was consumed in households. If this amount is observed in correlation with the official statistical data, it can be concluded that firewood sold from state forests was used in the amount of 597,776.06 m<sup>3</sup>. Further analysis and data on firewood consumption, indicating consumption in 497,139 households, show that the average consumption per household in the heating season 2015/2016, according to the official statistics on the sale of firewood originating from state forests, was 1.20 m<sup>3</sup> or 1.68 stacked cubic meters. The Statistical Bulletin (Institute for Statistics of the Federation of BiH 2016) provided no data on the sale of firewood originating from private forests, which are certainly a significant source of firewood for households, especially for those households outside urban areas.

More realistic data are obtained when considering the official statistical data on total felled timber in and outside state and private forests. Comparing the data on the total mass of 780,325 m<sup>3</sup> (Institute for Statistics of the Federation of BiH 2016) with the previously adopted assumptions about the percentage share in consumption and the number of households, it can be concluded that the average consumption in the heating season 2015/2016 per household was 1.44 m<sup>3</sup> or 2.02 stacked cubic meters. Using

the same assumptions, the average consumption of firewood per household in cantons in the Federation of BiH according to the official statistics is as follows: Bosnia-Podrinje Canton 3.19 m<sup>3</sup> or 4.46 stacked cubic meters; Herzegovina-Neretva Canton 0.98 m<sup>3</sup> or 1.37 stacked cubic meters; Canton 10 – 5.55 m<sup>3</sup> or 7.78 stacked cubic meters; Posavina Canton 0.10 m<sup>3</sup> or 0.14 stacked cubic meters; Sarajevo Canton 2.45 m<sup>3</sup> or 3.43 stacked cubic meters; Central Bosnia Canton 1.11 m<sup>3</sup> or 1.55 stacked cubic meters; Tuzla Canton 0.58 m<sup>3</sup> or 0.81 stacked cubic meters; Una-Sana Canton 2.74 m<sup>3</sup> or 3.84 stacked cubic meters; West Herzegovina Canton 0.22 m<sup>3</sup> or 0.31 stacked cubic meters; Zenica-Doboj Canton 1.86 m<sup>3</sup> or 2.60 stacked cubic meters.

On the other hand, observing the total number of households using firewood and the total consumption of firewood, the research presented in this paper using the WISDOM methodology indicates that the average consumption of firewood in households in the Federation of BiH was 5.91 m<sup>3</sup>, i.e. 8.27 stacked cubic meters, in particular: Bosnia Podrinje Canton 5.19 m<sup>3</sup> or 7.27 stacked cubic meters; Herzegovina-Neretva Canton 4.96 m<sup>3</sup> or 6.94 stacked cubic meters; Canton 10 – 8.12 m<sup>3</sup> or 11.37 stacked cubic meters; Posavina Canton 6.70 m<sup>3</sup> or 9.38 stacked cubic meters; Sarajevo Canton 5.82 m<sup>3</sup> or 8.14 stacked cubic meters; Central Bosnia Canton 7.36 m<sup>3</sup> or 10.31 stacked cubic meters; Tuzla Canton 4.37 m<sup>3</sup> or 6.12 stacked cubic meters; Una-Sana Canton 7.65 m<sup>3</sup> or 10.71 stacked cubic meters; West-Herzegovina Canton 4.37 m<sup>3</sup> or 6.12 stacked cubic meters; Zenica-Doboj Canton 5.74 m<sup>3</sup> or 8.04 stacked cubic meters (Figure 5).

Based on all the above, it can be concluded that data on the estimated consumption of firewood in households using the WISDOM methodology is 4.10 (when compared to the official statistics on total felled timber in and outside state and private forests) to 4.93 (when compared to the official statistics on the sale of firewood in state forests) times higher, i.e. in average 4.52 times higher in relation to the official statistical data.

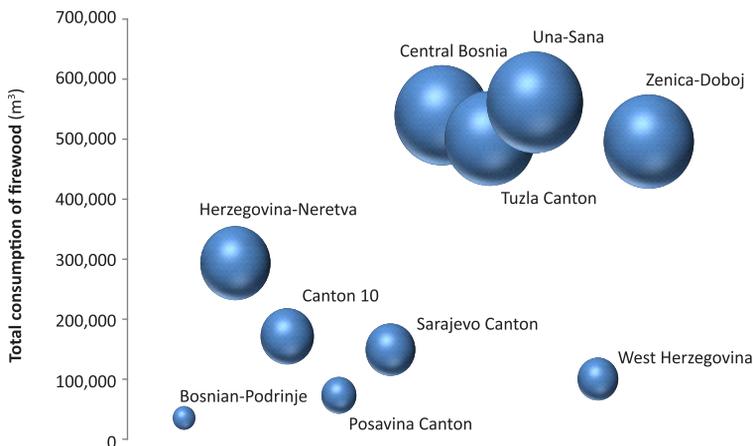


Figure 4. Total and relative consumption of firewood in the Federation of BiH cantons in the heating season 2015/2016.

The difference in average household consumption between the official statistics and data obtained using the WISDOM methodology is graphically presented in Figure 6.

Considering the above, it is evident that official statistical data often do not show the realistic situation. Since the average consumption of firewood per household in four cantons was less than 1 m<sup>3</sup>, namely in two cantons 0.1 m<sup>3</sup> and 0.22 m<sup>3</sup>, the relevance of official statistical data is questionable.

If the results obtained using the WISDOM methodology in the Federation of BiH are compared with the average consumption of firewood in the countries of the region estimated by using the same (WISDOM) methodology, they are as follows: 5.49 m<sup>3</sup>·household<sup>-1</sup> (7.67 stacked cubic meters)

in Montenegro (Marinović et al. 2013), 7.30 m<sup>3</sup>·household<sup>-1</sup> (10.22 stacked cubic meters) in Serbia (Glavonjić 2011, Glavonjić et al. 2015), 6.50 m<sup>3</sup>·household<sup>-1</sup> (9.10 stacked cubic meters) in Slovenia (Drigo and Veselić 2006) and 6.31 m<sup>3</sup> (8.84 stacked cubic meters) in Macedonia (Trajanov et al. 2018). It is evident that the data are similar. As for comparison, Granic et al. (2008) state that average consumption in the Federation of BiH was 8.6 m<sup>3</sup>, while Robina and Lončarević (2017) state that households in BiH used an average of 7.7 m<sup>3</sup> of solid biofuels per year.

Analyzing the relative differences between the data obtained using the WISDOM methodology and official statistical data for the Federation of BiH, similar trends with the surrounding countries are evident. Using the WISDOM

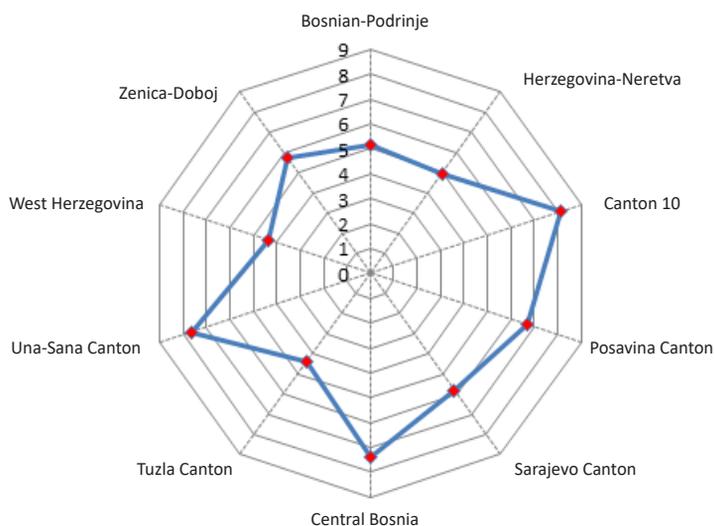


Figure 5. Average consumption of firewood in the Federation of BiH cantons according to the WISDOM methodology (m<sup>3</sup>·household<sup>-1</sup>).

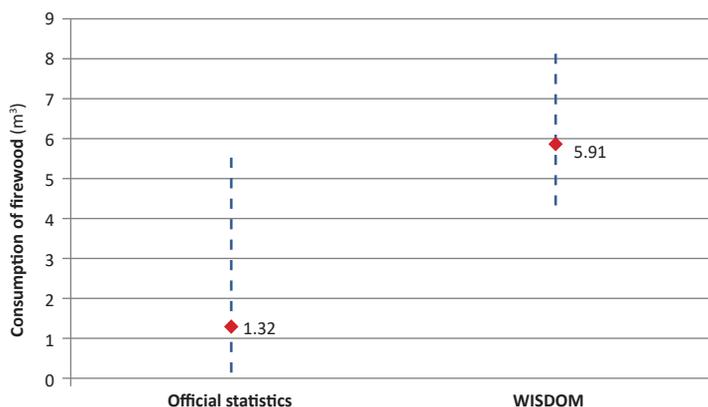


Figure 6. Consumption of firewood per household in the Federation of BiH according to the official statistical data and data obtained using the WISDOM methodology (m<sup>3</sup>·household<sup>-1</sup>).

methodology, 4.9 times higher consumption of firewood was determined in households in Serbia in the heating season 2010/2011 compared to official statistics (Glavonjić 2011), even 5.1 times higher consumption in Montenegro in the heating season 2011/2012 (Glavonjić and Krajnc 2013), and 1.7 times higher in Macedonia in the heating season 2015/2016 (Trajanov et al. 2018, State Statistical Office of the Republic of Macedonia 2016).

Considering the above research results and relevant bibliography, the relevance of official statistical data on the consumption of firewood, i.e. the share of registered consumers of firewood in total consumption, is questionable. Previous research (Granić et al. 2008) indicates that there were approximately 60% of registered consumers of firewood in BiH, while Robina and Lončarević (2017), referring to other research and studies, indicate that data on actual biomass consumption in households may differ significantly from those officially recorded. The authors further stated that most official reports on biomass consumption consider only firewood originating from state forests, but that in most cases households use wood from their own forests and do not officially report the amount of wood logged and used for energy purposes.

The use of biomass is not registered since statistical offices collect and publish data only on official trade in wood biomass, while the use of wood biomass for heating local communities located near forest areas and the use of wood by private forest owners is not recorded, which was confirmed by the research conducted for the World Bank (Stojadinović et al. 2017). This is followed by the land registry issues, unresolved property ownership rights and strict legal regulations, due to which some private forest owners cannot legally use firewood and other types of wood from their own forests since it is impossible to obtain valid proof of ownership documents. The problem of private forest ownership, including restrictions related to more effective mobilization of wood from private forests, has been covered in detail by PRIFORT project research (Glück et al. 2010).

A key precondition for improving the current state in private forests in all Western Balkan countries are the associations of private forest owners, namely the readiness of forest owners to form such associations. Although there are no consistent empirical data on the scope and type of illegal activities in forestry, the differences in the results on firewood consumption obtained using the WISDOM methodology and data available to the Institute for Statistics of the Federation of BiH can be partly explained by this problem. Forestry experts believe that the lack of adequate measures to combat corruption is one of the most serious problems in the forestry sector in the Federation of BiH (Avdibegović et al. 2014).

Survey which is described as a new research approach (Robina and Lončarević 2017), on which the WISDOM methodology is based, has indicated that the consumption of solid biofuels was 52.62% in 2009 and 52.02% in 2010, in relation to the consumption in 2014. They further state that the data on this almost double increase are the result of the application of a new research approach, and that they do not represent a real increase in the consumption of solid biofuels. Previously (refers to 2009 and 2010), data on solid biofuel consumption were based on statistical and other data of relevant institutions and organizations. Actual data

(refers to 2014) on wood fuel consumption in households for energy purposes were obtained after the adoption of a new approach and comprehensive research on the consumption of wood fuels for heating in households. Considering all the above, the authors (Robina and Lončarević 2017) conclude that data on the consumption of energy obtained from solid biofuels in the past were not relevant, which was confirmed by the results of research under FAO project presented in this paper.

## CONCLUSIONS

Firewood and other wood fuels are an important renewable energy source and very important economic resource that enables the development of the entire economy. Although large amounts of biomass are not used effectively, sustainable energy supply in the Western Balkans countries is essential for the regional economic growth and meeting EU accession commitments (Stojadinović et al. 2017). Sustainable and more efficient use of wood fuels for heat energy will contribute to increasing the share of renewable energy by using local energy sources, which are CO<sub>2</sub> neutral and at the same time have a positive economic impact and effects on employment. Considering a carbon-neutral source, it must be emphasized that in an effort to reduce CO<sub>2</sub> emissions by using energy from biomass, the environment must not be endangered since uncontrolled logging can cause forest degradation (Sulaiman et al. 2020).

Lack of reliable data on available wood biomass, wood fuels and their supply and demand/consumption in households, public institutions, industry and other categories of consumers prevents the application of various measures and instruments (regulatory, financial, planning, promotional and other) for the sustainable use of available energy potentials based on wood. The results presented in this paper indicate that the use of the WISDOM methodology enables overcoming of the lack of relevant information on wood fuel consumption. In addition, the WISDOM provides an assessment of the potentials and contribution of wood-based energy to meet national and international targets and plans for the participation of renewable sources in total energy consumption. Relevant data on wood fuel consumption represent the basis for future strategic planning in the energy sector and the use of renewable energy sources, as well as in forestry, environmental protection and related sectors.

Considering the main goal of determining the actual consumption of wood fuels in households in the Federation of BiH, by comparing the results of research obtained by the WISDOM methodology with official statistics on the recorded consumption, it can be concluded that the consumption of firewood in households was higher, as follows:

- 4.10 times when compared to the official statistical data on total felled timber in and outside state and private forests,
- 4.93 times when compared to the official statistical data on the sale of firewood in state forests, i.e.,
- 4.52 times in average.

Given the absolute amounts, the average consumption of firewood in households in the Federation of BiH in the heating season 2015/2016 was 5.91 m<sup>3</sup>, or 8.27 stacked cubic

meters. This type of wood fuel was present in more than 96% of households in the Federation of BiH that use wood fuels. On the other hand, official statistics show an average consumption of 1.32 m<sup>3</sup> (1.85 stacked cubic meters) per household.

The results obtained using the WISDOM methodology show a lack of reliability of the existing official statistics. Some of the causes are the neglect of statistically unrecorded production of firewood from private forests (to a large extent) and from areas not categorized as forests and forest land. In addition, incomplete coverage is evident in terms of conducting consumption research in all the most important categories of consumers and all categories of wood fuels. The above will, in addition to the negative economic consequences, affect the (im)possibility of providing relevant evidence of fulfilment of commitments in terms of the participation of renewable energy sources and greenhouse gas emissions. One of the greatest consequences is the impossibility of drafting relevant planning documents in forestry, with further negative consequences for the sustainability of the complex forest ecosystem.

Based on the results of research related to the consumption of wood fuels in the Federation of BiH, the most important recommendations for improving the current situation in this area are as follows:

- As stated in the Energy Community Study (2012a), consumption surveys should be included as one of the basic tools for collecting data on energy consumption in all consumption sectors. Annual specific surveys on biomass consumption would be the best way to ensure reliable statistics for estimating biomass consumption in households.
- Entity statistical offices, as well as the Agency for Statistics of Bosnia and Herzegovina, should be more involved in the implementation of the defined and implemented WISDOM methodology in future surveys of wood fuel consumption.
- Relevant institutions in the field of forestry should further encourage sustainable production of wood biomass, thus making a significant contribution to the faster development of its production.
- It is necessary to intensify efforts to apply various instruments (financial, regulatory, planning and promotional) and to find new models with the use of good foreign practices, such as "small scale cooperatives", energy plantations, combination

with carbon credits etc. for the increased use of wood biomass.

- To initiate a discussion at the state (BiH) and entities' levels regarding potential incentives for producers and/or discouraging the export of wood fuels (by encouraging domestic consumption), as a carbon neutral and renewable energy source, which would indirectly increase domestic consumption.
- Competent state, entity and local institutions, in cooperation with international organizations, should support the implementation of projects to replace fossil fuels with wood fuels, in order not to export the largest quantities of produced wood fuels in Bosnia and Herzegovina, but to use them. A wider framework includes measures such as incentives, subsidies and special purpose credit lines ("green credit lines"), as well as strategic programs of environmental education and strengthening public awareness.
- To intensify activities on establishing and strengthening the official national association for biomass as one of the urgent tasks in the future.

### Author Contributions

DRČ, BDG, MHA conceived and designed the research; BDG, DRČ, MHA carried out the field measurements; BDG, DRČ and NDA processed the data and performed the statistical analysis; BDG and MHA supervised the research and helped to draft the manuscript; DRČ wrote the manuscript.

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### Conflicts of Interest

The authors declare no conflict of interest.

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