

Project title: Inventory of wood energy consumption and GHG emissions from wood fuels in
Southern Serbia, Central Serbia, Western Serbia and Belgrade region

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**Inventory of wood energy consumption and GHG emissions
from wood fuels in Southern Serbia, Central Serbia,
Western Serbia and Belgrade region**

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PREFACE

The project “**Inventory of wood energy consumption and GHG emissions from wood fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region**” was implemented between December 2022 and March 2023, funded by the FAO organization in accordance with the Project number: TCP/SRB/3801/C1.

This project is a continuation of research that was carried out in the first half of 2021 in two regions in Serbia, in Vojvodina and Eastern Serbia. With these two projects, they covered all regions in Serbia. Research in this project was carried out according to the same methodology as in the project from 2021. **Therefore, the form and content of this report are fully compatible with the form and content of the report on the consumption of wood energy in the regions of Vojvodina and Eastern Serbia. In that way, the obtained results can be used for the level of Serbia, and not only for individual regions.**

The aim of the research on the inventory of wood energy consumption **in Southern Serbia, Central Serbia, Western Serbia and Belgrade region**” was to collect the data on types, amounts, and values of wood fuels being consumed in these regions in Serbia, as well as GHG emissions from their combustion. In addition, through this research, data on sources of wood fuel supply were collected, as well as the data on appliances used for their combustion.

The research included the most important categories of wood energy consumers:

- (i) households (urban and rural)
- (ii) public buildings (schools, health-care centres, ambulances, kinder gardens, local government facilities, etc.),
- (iii) commercial buildings (restaurants, meat roasters, bakeries, car repair services, shops, business facilities, etc.),
- (iv) district heating systems,
- (v) CHP plants and
- (vi) wood fuels producers (producers of pellets, briquettes, wood chips).

Based on the results of the inventory of wood fuels consumption, the corresponding balance of GHG emissions was developed. The inventory included a calculation of the emissions of carbon dioxide and nitrogen oxides.

This report contains the assessment of the interest of households in planting forests on abandoned agricultural and other bare lands in the selected regions: Southern Serbia, Central Serbia, Western Serbia, and Belgrade region.

I am grateful to all participants in the project who contributed to the improvement of the existing methodology, and for collecting the data on the consumption of wood energy in the selected regions in Serbia.

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Abbreviations and symbols

Loose m ³ (Bulk m ³)	Loose m ³ is the unit for the bulk material – typically for wood chips
m ³	Solid cubic meter. A cubic meter of compact wood is a measurement unit that indicates a volume completely filled with a wood content.
stacked m ³	Stacked cubic meter. The stacked cubic metre is the unit of measurement used for neatly stacked log woods.
LPG	Liquefied petroleum gas
t	Tonne
kWh	Kilowatt-hour
MJ	Megajoule
TJ	Terajoule
FAO	The Food and Agriculture Organization

Symbols

Not any = -

Data not available = ...

Data less than 0.5 of the unit given = 0

LIST OF TABLES AND FIGURES

LIST OF TABLES		
Tables	Title of the table	Page
1	Sample size per selected region 12	12
2	The value of the emission factors depends on different moisture content	15
3	Structure of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region by number of household members	16
4	Age and existence of thermo-insulation on residential buildings of households that consume solid fuels for heating	18
5	Facilities by the average number of rooms and average area	20
6	Age of windows and doors in the residential facilities in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	21
7	Number of residential facilities with windows that have or do not have thermo-insulating glass in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	22
8	Wood fuels consumption in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023	23
9	Indicators of the firewood consumption efficiency in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region	25
10	Consumption of wood fuels in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in 2010 and 2022	25
11	Consumption of wood fuels in public and commercial buildings and industry in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	33
12	Total wood fuels consumption in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023	34
13	Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Southern Serbia during the heating season 2022/2023	39
14	Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Central Serbia during the heating season 2022/2023	40

15	Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Western Serbia during the heating season 2022/2023	41
16	Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Belgrade region during the heating season 2022/2023	42

LIST OF FIGURES		
Figure	Title of the figure	Page
1	Position of the selected regions on Serbian map	10
2	Methodology for determining the number of households that use solid fuels for heating purposes in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	12
3	Share of the households with different number of members in the total number of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	17
4	Distribution of households with and without thermal insulation in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	19
5	Presence of certain fuel types for heating households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in the heating season 2022/2023	24
6	Average prices at which households purchased firewood in Southern Serbia, Central Serbia, Western Serbia and Belgrade region during the heating season 2022/2023	26
7	Timing of purchase of firewood by households relative to the beginning of the heating season in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023	28
8	Firewood supply chains of the households in the selected regions	29
9	The presence of particular types of heating systems in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region	31

10	Frequency of certain age ranges of heating appliances in surveyed households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	32
11	Awareness of the local population about the existence of abandoned agricultural and other bare lands in the selected regions	35
12	Awareness of local populations about the possibilities of income from planting forests or energy crops	36
13	Results of the survey on the interest of the interviewees for planting forests on abandoned agricultural and other bare lands in the selected regions	37
14	Percentual increase/decrease of the GHG emissions from firewood of different moisture content (relative to the purchasing period and derived from the emissions of wood purchased 6 months before the heating season)	43

Table of Contents

PREFACE.....	2
Abbreviations and symbols	3
1 METHODOLOGY APPLIED FOR DETERMINING WOOD ENERGY CONSUMPTION AND GHG EMISSIONS FROM WOOD FUELS IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION.....	10
1.1 METHODOLOGY APPLIED FOR DETERMINING WOOD ENERGY CONSUMPTION IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION.....	11
1.1.1 Sample and methodology for field survey.....	11
1.1.2 Interviewing of households.....	13
1.1.3 Interviewing in commercial buildings.....	13
1.1.4 Interviewing in public buildings and district heating systems.....	14
1.1.5 Survey on wood-processing industry and wood fuel producers	14
1.1.6 Data processing	14
1.2 CALCULATIVE METHODOLOGY OF GHG EMISSIONS STEMMING FROM THE WOOD FUELS COMBUSTION PROCESS IN THE SELECTED REGIONS.....	14
2 WOOD ENERGY CONSUMPTION IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION.....	16
2.1 Wood fuels consumption in households by region.....	16
2.1.1 Structure and characteristics of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region.....	16
2.1.2 Age and possession of thermo-insulation on residential buildings that use solid fuels for heating.....	17
2.1.3 Residential facilities by average number and area of rooms in the households that use solid fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	19
2.1.4 Residential buildings by the manner of use and age of windows and doors in households that use solid fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	21
2.1.5 Number of residential facilities which have windows with or without thermo-insulating glass.....	21
2.1.6 Consumption patterns of wood fuels in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	22
2.1.7 Purchase and storage of firewood for heating of households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region.....	27
2.1.8 Supply channels and the most frequent purposes for which firewood is used in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region	29

2.1.9	Heating systems and characteristics of the heating appliances in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region	30
2.2	Wood fuels consumption in public and commercial buildings and industry for energy purposes	33
2.3	Review of the total consumption of wood fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	34
2.4	The interest of households for planting forests on the abandoned agricultural and other bare lands in Southern Serbia, Central Serbia, Western Serbia and Belgrade region	35
3	BALANCE OF THE GHG EMISSIONS STEMMING FROM THE WOOD FUELS COMBUSTION IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION	38
4	CONCLUSIONS AND RECOMMENDATIONS	44
5	USED REFERENCES	48

The Goals of the project

The main goals of this project were:

- (i) conducting the inventory of wood energy consumption in the regions of Southern Serbia, Central Serbia, Western Serbia and Belgrade region in accordance with the methodology by using the method of direct surveys of the most important categories of wood energy consumers ((i) households (urban and rural households), (ii) public buildings (schools, health-care centres, ambulances, kinder gardens, local government facilities, etc.), (iii) commercial buildings (restaurants, meat roasters, bakeries, car repair services, shops, business facilities, etc.), (iv) district heating systems, (v) CHP plants, (vi) wood industry,
- (ii) updating the methodology for estimating the current greenhouse gas emissions from firewood combusted in the regions of Southern Serbia, Central Serbia, Western Serbia and Belgrade region covering all the most important categories of wood fuels, in accordance with the requirements arising from the structure of greenhouse gas balances of biomass.
- (iii) investigating the interest of households for planting the forests on the abandoned agricultural and other bare lands.

1 METHODOLOGY APPLIED FOR DETERMINING WOOD ENERGY CONSUMPTION AND GHG EMISSIONS FROM WOOD FUELS IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION

For realisation and completion of the project goals, the methodology applied comprehended two segments:

1. Conduction of wood energy consumption inventory, and
2. Calculation of the GHG emissions from the wood fuels combustion processes

The methodological concept used within the WISDOM projects in Serbia, Montenegro, Bosnia and Herzegovina, North Macedonia and Albania was adopted in this research as well. Those projects were conducted in the period 2010-2017 by FAO and the corresponding ministries.

The most important elements of the methodology used for the conduction of the wood energy consumption in the inventory in the chosen regions are shown underneath.

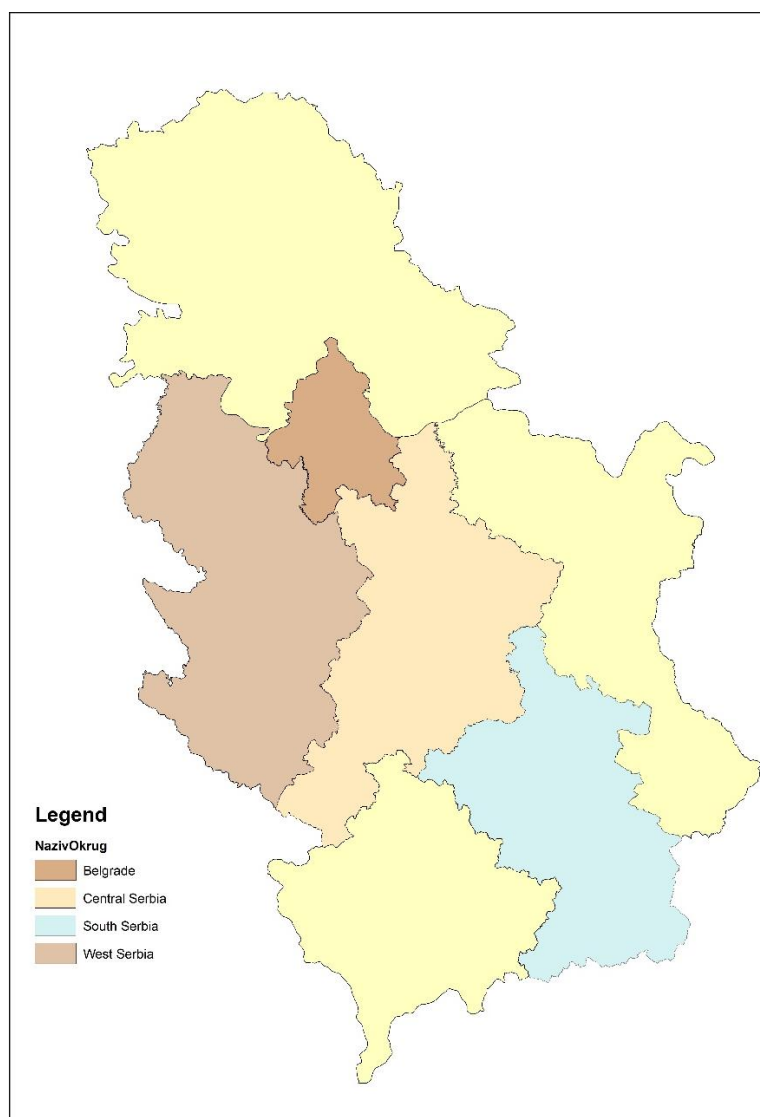


Fig. 1. Position of the selected regions on Serbian map

1.1 METHODOLOGY APPLIED FOR DETERMINING WOOD ENERGY CONSUMPTION IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION

The methodological concept implemented to the examination of the wood energy consumption in four Serbian regions was developed in a way that it can comprehend all significant consumer categories. It takes into consideration the consumers' size and number. Furthermore, the presence of households in the total (statistical) population was very well reflected in the sample. The data about other consumers' categories were gathered through direct interviewing and covers either all of them, like district heating systems and wood fuels producers), or most of them (like public, commercial and industrial facilities) in the chosen regions. All that guarantees a high level of data confidence and relevance for assessing the objective representation of the wood energy consumption in these two regions.

1.1.1 Sample and methodology for field survey

As the basis for determining the sample for interviewing of households were used the results from the census conducted in 2011. This sample could include only those households that use solid fuels for heating.

In the selected methodological approach, the total number of households registered in four selected regions (Southern Serbia, Central Serbia, Western Serbia and Belgrade region) in the last census conducted in 2011 was used as the starting point. The selection of such an approach resulted from the fact that it was the only reliable source of data on the households in urban and rural areas by settlements, towns and counties. The second important element of the selected methodological approach referred to the need to conduct the stated research on a county level because of differences among counties in Serbia mostly regarding climate characteristics, household size, the tradition in using certain fuels for heating, availability and convenience of using certain fuels (wood, coal, agricultural biomass and others) and socioeconomic factors (income level, level of equipping with various combustion devices, etc.).

Out of the stated number of households, those households using either district heating systems, electricity, natural gas or fuel oil for heating were deducted in order to obtain the number of households that use solid fuels such as wood, coal, briquettes, pellets or combined fuels (fig. 2).

The calculated number of households using solid fuels in Serbia represented the basis for conducting further research in order to observe not only the number of households using specific forms of solid fuels but also the volume of their consumption individually and on average per household expressed in cubic meters or tonnes.

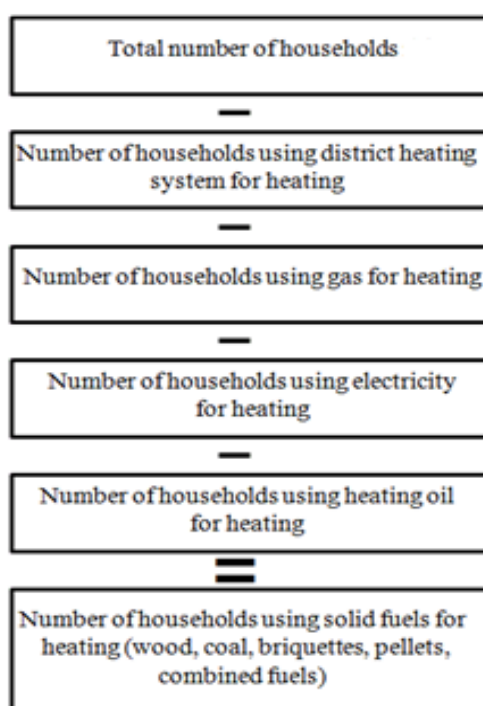


Fig.2. Methodology for determining the number of households that use solid fuels for heating purposes in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

For this project, the sample was 4,024 households. The number of the interviewed households per region (divided by urban and other) is given as followed (see table 1).

Table 1. Sample size per selected region

Region	Sample size	Number of urban households	Number of other households
Belgrade region	1,516	1,268	248
Southern Serbia	691	372	319
Central Serbia	1,001	534	467
Western Serbia	816	364	452
TOTAL	Total 4,024	Urban 2,538	Rural 1,486

After determining the sample, the following methodological steps were made:

1. To determine the sample size in selected regions was used the same percentage as each region had in the total number of households that used solid fuels. The total

number of 4,024 households in the sample was multiplied by that percentage and thus was obtained the sample for each region.

2. A sampling of the number of households in particular county within the region was done in the same way. The number of households in the sample in certain towns/municipalities within the county was determined using the same approach.
3. The division of such sampled households into “urban households” and “other households” was based on a share of those two categories (urban and other) in the total number of households at the level of town/municipality.
4. The selection of households for the sample in each town was random and stems from the database covering over 60,000 households. The software tool used was the programme package “*Statistica V.7.0*”. This database contains all information on the consumption of solid fuels for heating, which was necessary for sampling, organization, and conduction of the research. It has been covering this topic for the last twelve years and has already been used in similar projects conducted in the mentioned period. The households in the database were grouped into urban and other.
5. Each sample of households on the level of a town contained the main and the so-called replacing households. The replacing households were only used in the cases when some of the main households rejected to participate in the interview. The approach of selection of the replacing households was the same as the logic behind the selection of the main households, i.e. random selection was applied for both categories of households.

1.1.2 Interviewing of households

Households were interviewed between December 15th, 2022, and March 10th, 2023. Interviewing was conducted in all urban settlements, and in the two biggest other (rural) settlements in every city/municipality. A total number of 4,024 households were interviewed for the selected regions, as follows:

- Households in urban settlements: 2,538
- Households in other settlements: 1,486

The collection of data on wood fuel consumption and characteristics of buildings and appliances for wood fuels combustion was conducted using the appropriate questionnaire.

1.1.3 Interviewing in commercial buildings

A survey on wood and wood fuel consumption in commercial buildings had the intention to ensure proper geographical distribution in the entire four selected regions. The questionnaire

for commercial buildings contains significantly fewer questions than the one for households. 284 commercial buildings were interviewed, mostly from the following categories: bakeries, shops, restaurants, car repair centres, hair salons, hotels, etc.

1.1.4 Interviewing in public buildings and district heating systems

For wood fuel consumption research purposes, interviewing included the following:

- District heating systems in 16 local communities;
- 88 administrative buildings;
- 44 health institutions;
- 291 kindergarten and school institutions.

1.1.5 Survey on wood-processing industry and wood fuel producers

Methodology defined the criteria to interview the largest wood processing companies, i.e. those that produce semi-finished or finished products. This project included 296 industry enterprises. Additionally, 59 wood fuel producers were identified and interviewed (this includes wood chips, wood briquettes and wood pellets).

1.1.6 Data processing

After interviewing and entering the data into the digital application, the entered data were checked, logical control of consumption in physical measurement units per m² of the heating surface was conducted, and then the data were processed, systematized and calculated from the level of a sample to the level of a whole.

1.2 CALCULATIVE METHODOLOGY OF GHG EMISSIONS STEMMING FROM THE WOOD FUELS COMBUSTION PROCESS IN THE SELECTED REGIONS

The calculation of the GHG emissions from the wood fuels combustion process in the chosen regions was based on the IPCC 2006 methodology and additions from the corresponding European standards, relevant scientific papers and publications measurements from practice.

The starting equation for calculating the GHG emissions from the stationary wood fuels combustion was the equation from the methodological instructions of IPCC 2006:

$$\text{Emissions}_{GHG, fuel} = \text{Fuel consumption}_{fuel} \times \text{Emission Factor}_{GHG, fuel} \quad (1)$$

where:

Emissions_{GHG, fuel} = emissions of a given GHG by type of fuel (kg GHG)

Fuel Consumption_{fuel} = amount of fuel combusted (TJ)

Emission Factor_{GHG, fuel} = emission factor of a given GHG by type of fuel (kg gas/TJ). For CO₂, it includes the carbon oxidation factor, assumed to be 1.

Different wood fuels contain different levels of moisture (moisture content- MC). The emission factors are different for different levels of moisture. For the GHG balancing in this project, the emission factor was determined for different wood moisture levels. That was based on the standard EN 16449:2014 and the following parameters:

$$P_{CO_2} = \frac{44}{12} \times cf \times \frac{\rho_w \times V_w}{1 + \frac{w}{100}}$$

where

P_{CO_2} is the biogenic carbon oxidized as carbon dioxide emission from the product system into the atmosphere (e.g. energy use at the end-of-life) (kg);

cf is the carbon fraction of woody biomass (oven dry mass), 0,5 as the default value;

w is the moisture content of the product (e.g. 12 (%));

ρ_w is the density of woody biomass of the product at that moisture content (kg/m³);

V_w is the volume of the solid wood product at that moisture content (m³).

For wood-based products, wood volume content $V_w = VP \times \text{percentage of wood}$.

VP is the gross volume of the wood-based product.

The results of the emission factors based on different wood moisture levels are shown in table 2.

Table 2. The value of the emission factors depends on different moisture content

Moisture content (%)	Emission factor kgCO ₂ per TJ	Moisture content (%)	Emission factor kgCO ₂ per TJ
10	104,539	30	118,995
15	106,818	35	125,446
18	108,619	40	133,553
20	109,934	45	143,880
25	113,974	50	157,439

Sources: 1. Author's calculations; 2. EN 16449: Wood and wood-based products - Calculation of the biogenic carbon content of wood and conversion to carbon dioxide; 3. EU Joint Research Centre

For wood pellets and wood briquettes, the emission factor amounts to 98,303 kg/TJ (MC=8%).

The CO₂ emissions from the combustion of wood fuels for certain levels of moisture were calculated by application of the equation (1). For the N₂O calculations in this project, the IPCC 2006 default emission factor of 4 kg per TJ was taken for all wood fuels and all levels of moisture. The emissions of SO₂ from the combustion of wood fuels are symbolically low. Therefore, they were not separately calculated in this project.

2 WOOD ENERGY CONSUMPTION IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION

Overview and characteristics of wood energy consumption in Southern Serbia, Central Serbia, Western Serbia and Belgrade region and its counties in 2022. is given based on the conducted interviewing of all major categories of consumers: households, public buildings, commercial buildings, wood fuels producers and wood industry.

2.1 Wood fuels consumption in households by region

Within this part of the Report, besides the overview of wood fuels consumption by certain types, there are also presented characteristics of households, their residential buildings and characteristics of their appliances for wood fuels combustion.

2.1.1 Structure and characteristics of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Data on the number of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region are given in Table 3.

Table 3. Structure of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region by number of household members

Region	Number of households with the number of household members					
	Total	1	2	3	4	5 +
Southern Serbia	199,736	21,616	70,902	32,569	43,521	31,128
Urban	119,034	13,258	38,333	18,734	28,245	20,464
Other	80,702	8,358	32,569	13,835	15,276	10,664
Central Serbia	269,837	27,110	59,740	40,162	75,052	67,773
Urban	138,809	13,304	28,615	22,842	43,927	30,121
Other	131,028	13,806	31,125	17,320	31,125	37,652
Western Serbia	227,281	14,555	57,100	27,990	62,978	64,658
Urban	103,844	6,158	19,593	13,715	35,548	28,830
Other	123,437	8,397	37,507	14,275	27,430	35,828
Belgrade region	111,586	7,469	18,524	16,694	33,901	34,998
Urban	92,694	5,857	15,156	13,692	28,116	29,873
Other	18,892	1,612	3,368	3,002	5,785	5,125

With the exception of Southern Serbia where is the dominant participation of households with 2 members (35.5%), households with 4 and 5 and more members are dominant in other regions (fig.3).

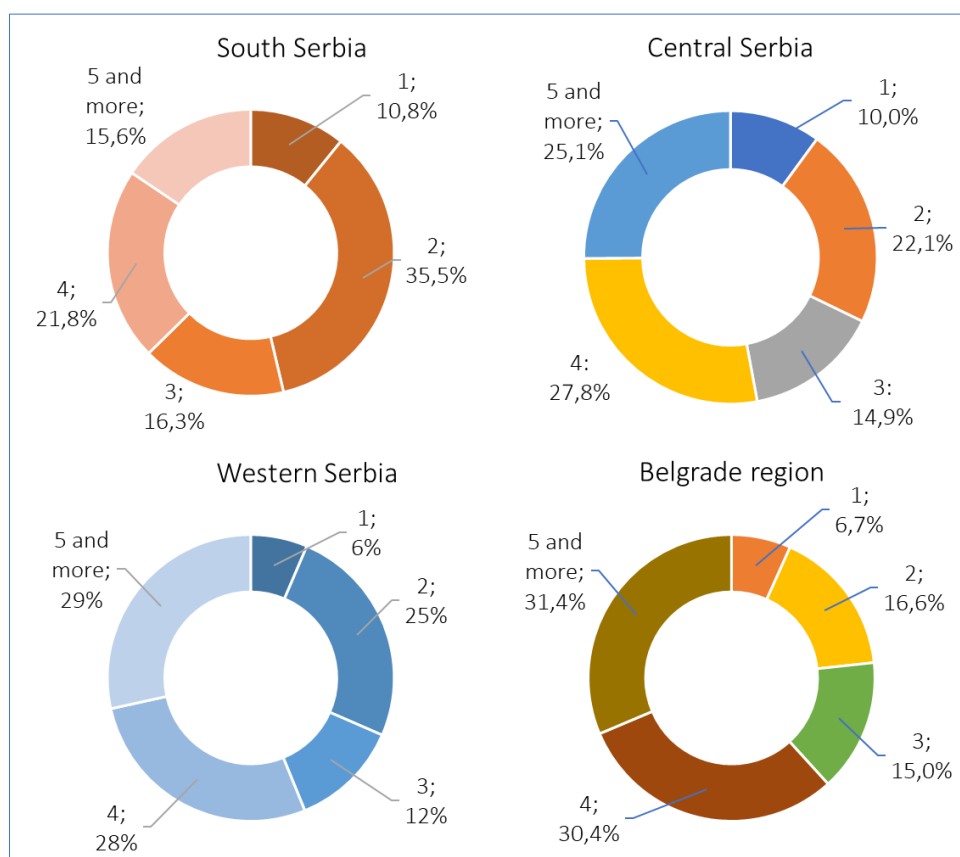


Fig. 3. Share of the households with different number of members in the total number of households that use solid fuels for heating in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

The dominant share of the households with two members in Southern Serbia is an indicator of the depopulation of this region and low standard of living. One of the consequences of this process is a connection of families into multi-member households. On the other hand, the merging of families into multi-member households in the Belgrade region is the result of high housing prices and the impossibility of each family having its own house or apartment.

2.1.2 Age and possession of thermo-insulation on residential buildings that use solid fuels for heating

A number of facilities with households that use solid fuels for heating which have thermo-insulation and their age, as well as the number of facilities with no thermo-insulation and their age, at the regional level are given in table 4.

Table 4. Age and existence of thermo-insulation on residential buildings of households that consume solid fuels for heating

Region	Number and age of buildings that have thermal insulation					Number and age of buildings that have not thermal insulation				
	Total	Buildings' age (years)				Total	Buildings' age (years)			
		Up 5	6-10	11-20	Over 20		Up 5	6-10	11-20	Over 20
SOUTHERN SERBIA	55,915	2,882	17,005	10,953	25,075	143,821	2,306	7,782	25,363	108,370
Urban	44,962	864	15,564	8,647	19,887	74,072	1,153	3,459	14,987	54,473
Other	10,953	2,018	1,441	2,306	5,188	69,749	1,153	4,323	10,376	53,897
CENTRAL SERBIA	114,712	5,020	7,530	28,365	73,797	155,125	1,004	2,511	11,546	140,064
urban	66,518	3,012	2,761	15,814	44,931	72,292	502	1,256	4,518	66,016
other	48,194	2,008	4,769	12,551	28,866	82,833	502	1,255	7,028	74,048
WESTERN SERBIA	121,198	6,438	21,833	27,990	64,937	106,083	1,120	3,079	4,199	97,685
urban	57,380	2,519	6,718	11,476	36,667	46,464	560	1,120	1,400	43,384
Other	63,818	3,919	15,115	16,514	28,270	59,619	560	1,959	2,799	54,301
BELGRADE REGION	63,700	2,562	4,979	15,376	40,783	47,886	367	805	6,004	40,710
urban	54,035	2,123	4,320	13,838	33,754	38,660	293	659	5,711	31,997
other	9,665	439	659	1,538	7,029	9,226	74	146	293	8,713

The first important characteristic of households that consume solid fuels for heating in the selected regions is a dominant share of those, whose residential buildings do not have thermal insulation in Southern Serbia (72%) and Central Serbia (57.5%). On the other hand, in Western Serbia (53%) and the region of Belgrade (57%), is the dominant share of buildings with thermal insulation (fig. 4). The second important feature of those residential buildings is their age: the majority is over 20 years old: in Central Serbia 79.2%, in Belgrade region 73%, in Western Serbia 71.6% and in Southern Serbia 66.8%. Such state of the residential buildings is unsatisfactory from the aspect of the conditions in which the wood fuels are consumed/combusted.

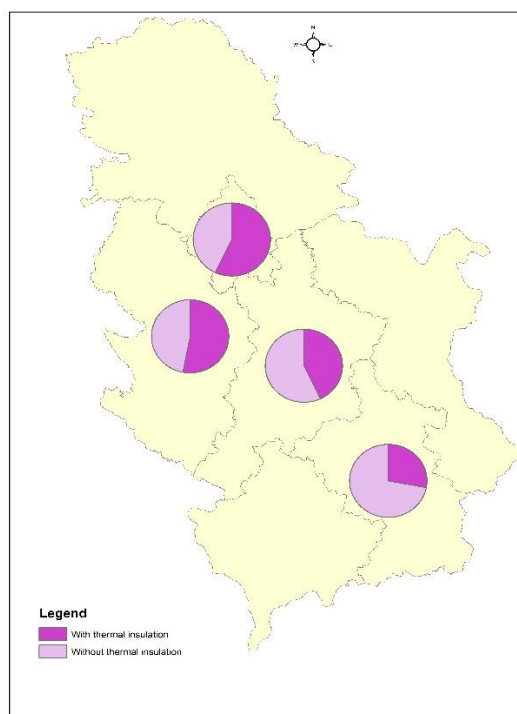


Fig. 4. Distribution of households with and without thermal insulation in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

With the exception of Western Serbia, where the share of other households that have thermal insulation is higher (53%), in the other regions, the dominant share in urban households, namely in Southern Serbia (80%), Central Serbia (58%) and the Belgrade region (85%).

2.1.3 Residential facilities by average number and area of rooms in the households that use solid fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Data on the average number of rooms in general and rooms being heated during the heating season as well as their average area in residential facilities of households that use solid fuel in Southern Serbia, Central Serbia, Western Serbia and Belgrade region are given in Table 5.

The highest average number of rooms in residential facilities (including kitchen, corridors, and WC/toilet) in urban settlements has Belgrade (7.6), followed by Western Serbia (6.6) and Central Serbia (6.2). In Southern Serbia, the average number of rooms per facility is significantly lower (5.3). The same order applies when it comes to the average number of rooms being heated during the heating season.

The average number of rooms in residential facilities (including kitchen, corridor and WC/toilet) in other settlements in Belgrade region is 7.5, while in other regions is 6.3 in Western Serbia, 6.1 in Central Serbia and 5.1 in Southern Serbia. The same order applies when it comes to the average number of rooms being heated during the heating season.

Table 5: Facilities by the average number of rooms and average area

Region/Households		The average number of total rooms in a facility (including kitchen, corridor and WC/toilet)	The average area of a facility [m ²]	The average number of rooms in a facility being heated during the heating season (including kitchen, corridor and WC/toilet)	Average area being heated in a facility during the heating season [m ²]
Southern Serbia	Urban	5.3	93.7	3.2	59.8
	Other	5.1	90.1	2.9	53.1
Central Serbia	Urban	6.2	97.4	4.0	64.1
	Other	6.1	95.3	3.6	60.4
Western Serbia	Urban	6.6	98.3	4.8	73.3
	Other	6.3	98.5	4.4	69.8
Belgrade region	Urban	7.6	108.2	5.9	81.2
	Other	7.5	107.4	5.3	77.5

The average area of residential facilities in the selected regions is between 93.7 m² and 108.2 m² in urban settlements i.e., between 90.1 m² and 107.4 m² in other settlements. The biggest average area of residential facilities in urban settlements is in Belgrade, both in urban (108.2 m²) and other settlements (107.4 m²).

The average area being heated in residential facilities during the heating season at the level of the Belgrade region is 81.2 m² in urban and 77.5 m² in other households. The smallest average area being heated during the heating season has Southern Serbia in the amount of 59.8 m² in urban and 53.1 m² in other settlements.

2.1.4 Residential buildings by the manner of use and age of windows and doors in households that use solid fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

An overview of the age of windows and doors in residential facilities in Southern Serbia, Central Serbia, Western Serbia and Belgrade region is given in Table 6.

Table 6. Age of windows and doors in the residential facilities in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Region	Number of residential facilities and age of windows and doors			
	Total	Age of windows and doors (in years)		
		0-10	11-20	More than 20
Southern Serbia	199,736	55,915	29,686	114,135
Urban	119,034	40,639	17,293	61,102
Other	80,702	15,276	12,393	53,033
Central Serbia	269,837	112,453	27,611	129,773
Urban	138,810	64,510	13,555	60,745
Other	131,027	47,943	14,056	69,028
Western Serbia	227,281	103,004	37,227	87,050
Urban	103,844	55,701	13,995	34,148
Other	123,437	47,303	23,232	52,902
Belgrade region	111,586	61,065	18,451	32,070
Urban	92,695	50,302	16,840	25,553
Other	18,891	10,763	1,611	6,517

In residential facilities in the Southern and Central Serbia, windows and doors are mostly over 20 years old. In Southern Serbia the share of windows and doors over 20 years old is 57%. In Central Serbia, the corresponding share is 48.1%. This is for sure an unsatisfactory situation when it comes to energy efficiency and intensively impacts wood energy consumption.

The opposite, the share of new windows and doors (the age of up to 10 years) is 45.3% in Western Serbia and 54.7% in Belgrade region.

2.1.5 Number of residential facilities which have windows with or without thermo-insulating glass

Data on the number of residential facilities which have or do not have windows with thermo-insulating glass, in Southern Serbia, Central Serbia, Western Serbia and Belgrade region are given in Table 7.

Table 7. Number of residential facilities with windows that have or do not have thermo-insulating glass in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Region	Type of a settlement	Number of facilities with windows that have an insulating glass	Number of facilities with windows that don't have an insulating glass
Southern Serbia	Total	86,466	113,270
	urban	57,356	61,679
	other	29,110	51,591
Central Serbia	Total	140,315	129,522
	urban	78,566	60,243
	other	61,749	69,279
Western Serbia	Total	128,755	98,526
	urban	62,978	40,866
	Other	65,777	57,660
Belgrade region	Total	80,541	31,045
	urban	67,362	25,334
	other	13,179	5,711

In Southern Serbia, 43.2% of residential facilities have windows with thermo-insulating glass, while 56.8% have windows without thermo-insulating glass. The situation is the opposite in the other three regions. In Central and Western Serbia 52% and 56.6% of residential facilities in these two regions have windows with thermo-insulating glass (over 1/2), while 48% and 43.4% do not possess thermo-insulating glass respectively. The best situation is in the region of Belgrade, where 72.2% of residential buildings have windows with thermal insulating glass.

2.1.6 Consumption patterns of wood fuels in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Total consumption of wood fuels in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023 is given in Table 8. Data in this table are structured to show consumption of certain wood fuels in households separately at the level of each selected region.

Table 8. Wood fuels consumption in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023

Region	Type of wood fuel	Unit	Quantity
Southern Serbia	Firewood	m ³	1,051,262
	Wood pellets	tonnes	45,880
	Wood briquettes	tonnes	28
Central Serbia	Firewood	m ³	1,386,075
	Wood pellets	tonnes	64,102
	Wood briquettes	tonnes	117
Western Serbia	Firewood	m ³	1,181,918
	Wood pellets	tonnes	64,355
	Wood briquettes	tonnes	93
Belgrade region	Firewood	m ³	490,554
	Wood pellets	tonnes	99,911
	Wood briquettes	tonnes	586

The wood fuels consumption differs significantly between the regions but the main characteristic of their consumption is the domination of firewood. The vast majority of households from all chosen regions consume only firewood. Only some of them consume firewood in combination with coal and electricity. Fig. 5 depicts the share of combinations of solid fuels in households per regions.

As it could be seen, in all selected regions firewood is a dominant fuel consumed by households for heating. Its share is in the range from 52.1% in Belgrade region to 85% in Southern Serbia. In Belgrade region, the households combine wood and coal (10.8%) and wood and electricity (13.4%) for heating. The share of households that consume only wood pellets is 18.1% while the share of households that use other solid fuels (individually or in combination) is 5.6%.

The fuels consumption in Southern Serbia is completely different. In this region, firewood is the dominant fuel with share of 85% in total households that use solid fuels. The share of households that consume wood pellets is 5.2%. The second important characteristic of the fuels consumption in the households from Southern Serbia is a small number of combinations of different fuels consumed for heating. For example, the share of the wood-electricity combination is 7%, and wood-coal is only 2.3%

The share of households that use only firewood is also over 80% in the other two regions. In Central Serbia it is 80%, and in Western Serbia is 82.9%. The important characteristic of the fuels consumption in the households from these two regions is a small number of combinations of different fuels consumed for heating. For example, the households that use a combination of wood and electricity participate with 9.9% in Central Serbia and 6% in

Western Serbia. The share of households that use wood pellets ranges from 5% in Central Serbia to 6.7% in Western Serbia.

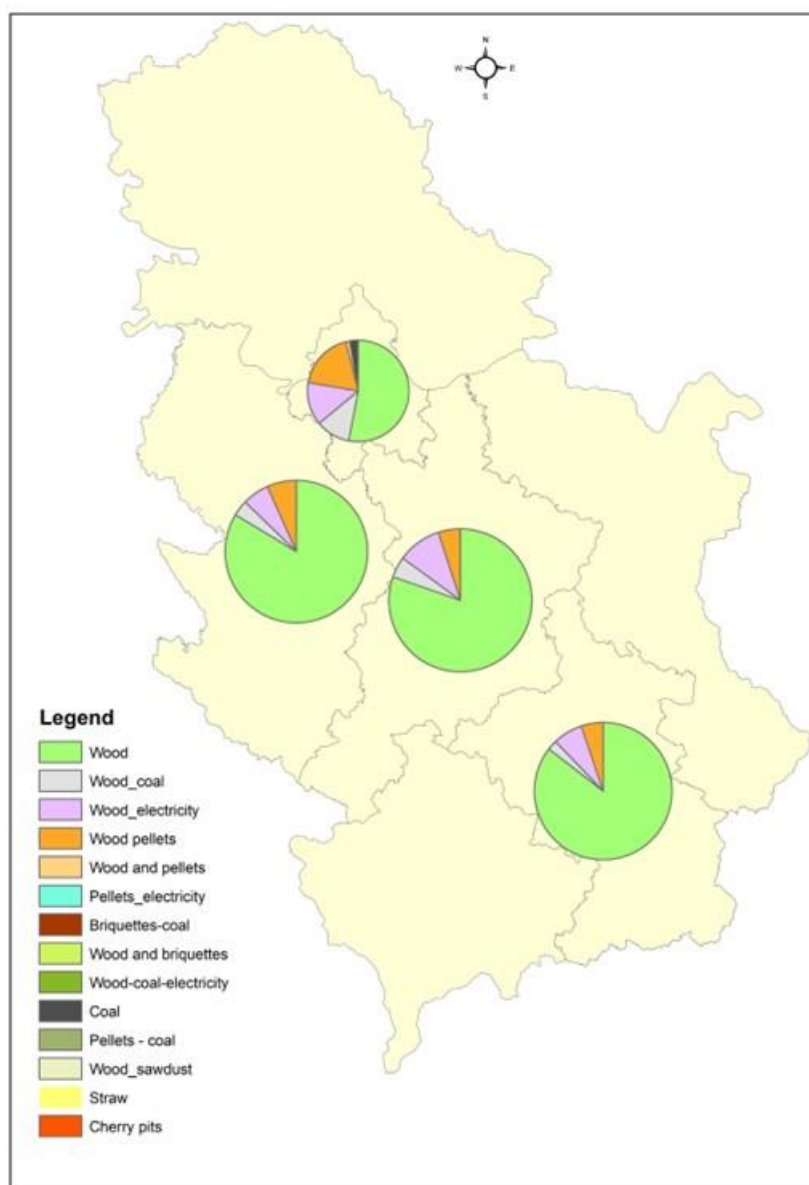


Fig. 5. Presence of certain fuel types for heating households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in the heating season 2022/2023

According to the survey conducted within this project, 14 different combinations of fuels have been registered. In those combinations, a symbolic participation of households using straw in Central Serbia (0.2%) as well as households using cherry pits in Western Serbia (0.1%) was recorded.

When it comes to the efficiency of the wood fuels consumption, it is assessed by the consumption indicators measured per household or per 1m² of the heated area. More details about these indicators in the chosen region could be found in table 9.

Table 9. Indicators of the firewood consumption efficiency in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Region		Firewood consumption [m ³ /household]	Firewood consumption [m ³ /m ² heated surface]	Wood energy consumption [kWh/m ² heated surface]
Southern Serbia	Urban	6.2	0.104	278.3
	Other	6.3	0.118	315.7
Central Serbia	Urban	6.0	0.092	248.1
	Other	6.3	0.104	280.3
Western Serbia	Urban	6.5	0.088	236.2
	Other	7.2	0.103	276.5
Belgrade region	Urban	5.6	0.069	185.9
	Other	5.8	0.075	202.1

The consumption of wood energy in the households measured in kWh/m² of the heated area is not satisfactory in all selected regions. Its values are beyond the values of the last class of the energy passport for residential buildings [G class > 188 kWh/m² (a)]. The only exception is urban households in the Belgrade region, whose average consumption per 1m² of heating surface is slightly lower compared to the threshold value of the G class of the energy passport.

From the aspect of the wood fuels consumption in the households from the chosen regions, it would be interesting to compare the development of the consumption between 2022 and 2010, in terms of quantity. The last big inventory of the wood fuels consumption in Serbia was done in 2010. In table 10, one may find the consumption from that year and the consumption from 2022.

Table 10. Consumption of wood fuels in households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in 2010 and 2022

Region	Type of wood fuel	Unit	Quantity		Change 2010 to 2020
			2010.	2020.	
Southern Serbia	Firewood	m ³	1,148,209	1,051,262	-8.4%
	Wood pellets	tonnes	336	45,880	136.5 times
	Wood briquettes	tonnes	232	28	-8.3 times
Central Serbia	Firewood	m ³	1,277,461	1,386,075	8.5%
	Wood pellets	tonnes	224	64,102	286 times
	Wood briquettes	tonnes	3,119	117	-26.6 times

Western Serbia	Firewood	m ³	1,218,695	1,181,918	-3.0%
	Wood pellets	tonnes	1,107	64,355	58.1 times
	Wood briquettes	tonnes	804	93	-8.6 times
Belgrade region	Firewood	m ³	406,209	490,554	20.7%
	Wood pellets	tonnes	643	99,911	155 times
	Wood briquettes	tonnes	2,465	586	-4.2 times

Sources: 1. WISDOM Serbia, FAO, 2015; 2. Households survey 2023.

The consumption of wood pellets in all selected regions increased dramatically between 2010 and 2020. The wood pellet has become a very popular and appreciated fuel amongst consumers in the last twelve years.

Firewood consumption increased in Central Serbia and Belgrade region while it fell in Southern Serbia and Western Serbia. The decline in firewood consumption in these two regions is the result of the process of the population's migration from these regions to bigger urban areas in other regions. This process is very prominent.

Wood briquettes consumption decreased in all regions as a result of the rapid growth in popularity and consumption of wood pellets.

Depending on the supply chain and the timing of purchase, the prices of firewood have strong local variation (fig. 6).

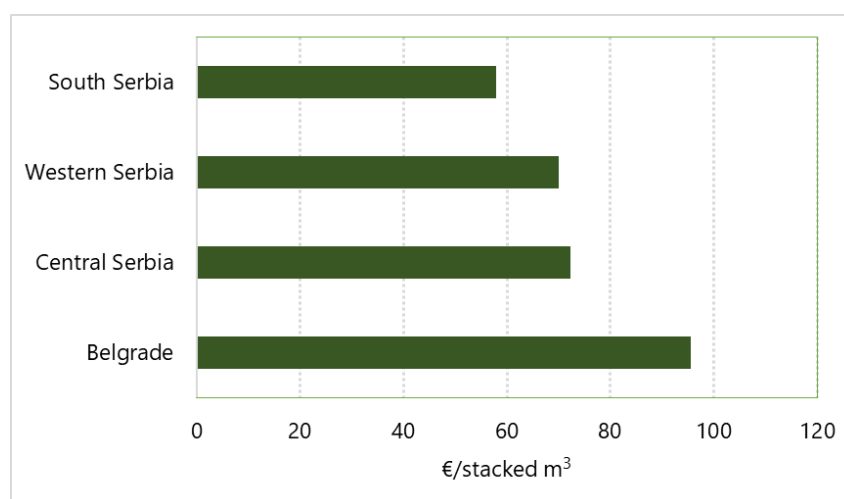


Fig. 6. Average prices at which households purchased firewood in Southern Serbia, Central Serbia, Western Serbia and Belgrade region during the heating season 2022/2023

The average firewood prices in the heating season 2022/2023 amounted to 58 € per stacked m³ in Southern Serbia to 95.6 € per stacked m³ in Belgrade region. Such a big difference in firewood purchase prices between the two regions arises from the fact that Southern Serbia is the one of the most forested region of the country. Hence, the availability of wood there is

significantly larger than in Belgrade region. Firewood prices in Western Serbia and Central Serbia were relatively uniform and ranged from €70 to €72 per stacked m³.

The average prices of wood pellets were also uniform in all regions ranged between €295 per tonne in Western Serbia to €357 per tonne in Belgrade region. The main characteristic of the pellet market in Serbia in 2022 has been the sharp increase in their prices. The global energy crisis and the war in Ukraine were the main triggers of the accelerated price growth. Average wood pellet prices in May 2022 were 75.5% higher compared to October 2021. It was the reason that the Government of Serbia banned the export of wood pellets and limited their price to 320 € per tonne including VAT. In Serbia, it was determined from August 2022. to the end of January 2023. In that way, the Government tried to stabilize the market and ensure sufficient quantities of wood pellets for domestic needs.

2.1.7 Purchase and storage of firewood for heating of households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Timing of firewood purchase relative to the beginning of the heating season is an important factor in firewood consumption because wood contains different quantities of water and that depends on the time between the moment of felling and the moment of consumption. For wood pellets and briquettes that is not the case, because their moisture is fixed in the technological process of production and amounts to approximately 8%. Reviews of households according to the timing of the purchase of firewood relative to the beginning of the heating season are given in fig. 7.

The largest number of households in all selected regions purchased firewood in 2022 some two to three months before the heating season. In Southern Serbia, as many as 53% of households that use firewood purchased it during that period. A similar situation is in Western Serbia (45%).

The share of households that purchased firewood some four to six months before the heating season is 28% in Belgrade region i.e. 27% in Central Serbia while it is significantly less in Western Serbia (16%) and Southern Serbia (12%).

The share of households that purchased firewood right after the end of the previous heating season is the largest in the Belgrade region (26%) and Western Serbia (20%), while in Central Serbia and Southern Serbia, their participation is 15% or 10% respectively.

The participation of households that purchased firewood up to year in advance or longer before the heating season is symbolically in all regions.

The partly purchased firewood before the heating season, and partly during the heating season amounts to 4% in Belgrade region and in Southern Serbia.

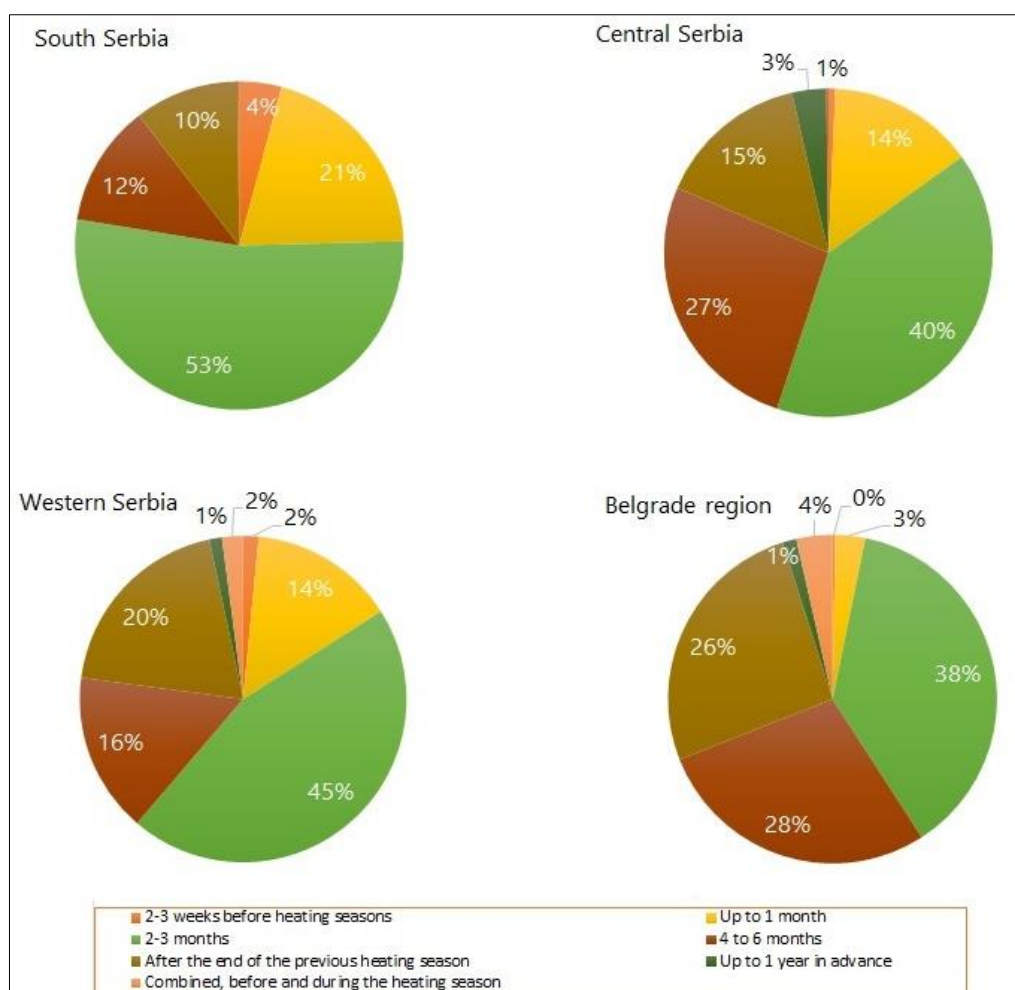


Fig. 7. Timing of purchase of firewood by households relative to the beginning of the heating season in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023

Generally, the firewood purchase by households is satisfactory in Belgrade region only because 59% of them purchase wood on time to dry and to reduce the moisture content below 30%. On that way, they can consume "dry wood" during the heating season.

On the question "why they consume the fuels they consume", 21% of the households in Belgrade stated that the devices for other fuels are too expensive for them, 20% that it is the cheapest solution for them and that their heating appliances need exactly those fuels (13.1%).

The main reason for the dominance of firewood in Southern Serbia is the cheapest fuel compared to the other fuels and easiness of its purchase, i.e. the availability. This was confirmed during the survey over 1/2 of the interviewed households. A similar situation is in Central Serbia and Western Serbia where most households have responded that firewood is the cheapest fuel for them as well as the easiness of its purchase.

When it comes to storing wood fuels, the situation is good in all regions except Belgrade because most of the households have covered storing facilities (mostly woodsheds). In Central Serbia, 63.4% of the households store their firewood in woodsheds, in Southern Serbia 58.6% and in Western Serbia 57%. In the Belgrade region, this percentage is 41 while 24% of them store their firewood in open spaces i.e. front of the house.

2.1.8 Supply channels and the most frequent purposes for which firewood is used in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region

The most important wood fuel supply channels for the households from Southern Serbia, Central Serbia and Western Serbia are their own forests and traders. Together, they supply 76% of the households in Western Serbia i.e. 62% of the households in Southern Serbia and 59% in Central Serbia. In Belgrade region, the supply channels are differentiated. Almost 85% of households provide firewood from two channels: heating fuels warehouses (56%) and from timber traders (29%) (fig.8). The share of state-owned forest as supply channel is symbolic in all regions.

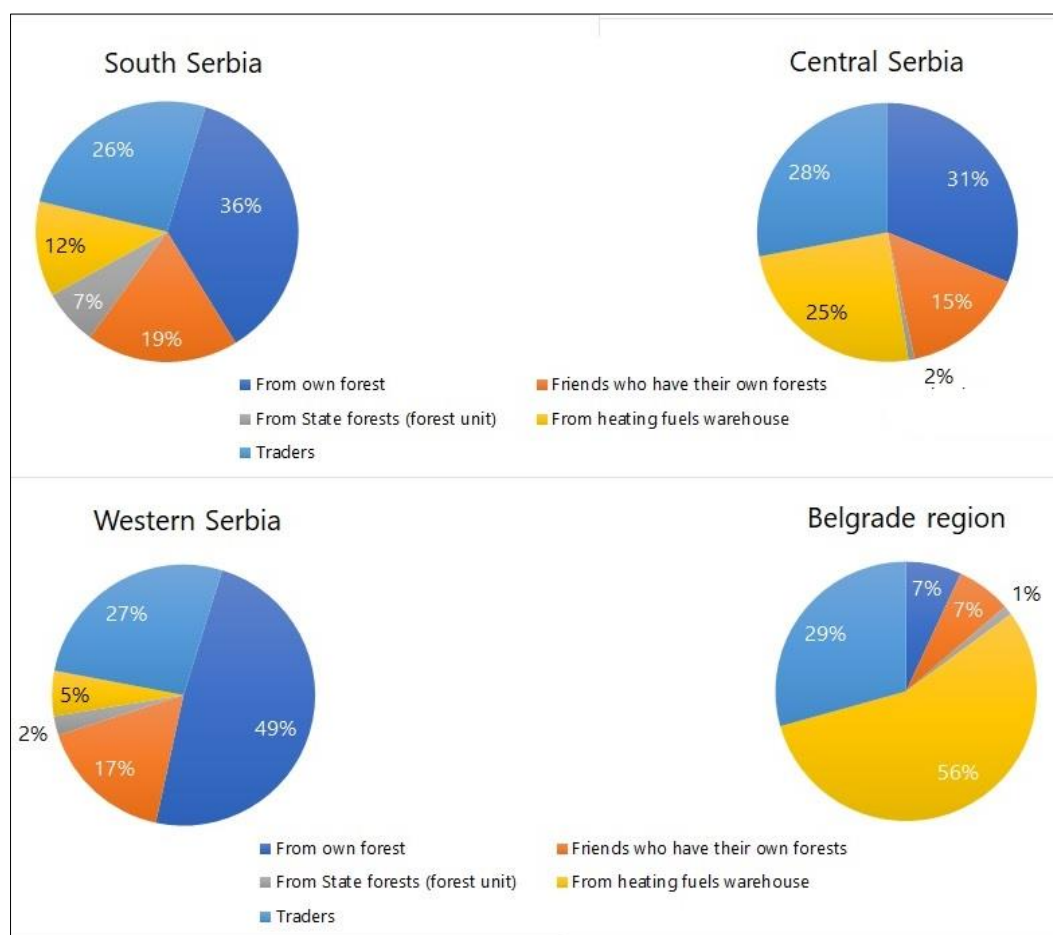


Fig. 8. Firewood supply chains of the households in the selected regions

The general conclusion is that households in all regions are predominantly supplied with firewood from private forests.

According to the survey, 71% of the households in Southern Serbia consume firewood for heating, hot water and cooking while 23.3% of them use it for heating only. The remaining 5.7% consume it additionally for the production of brandies and drying of meat and plums. The situation in the other three regions is somewhat different compared to Southern Serbia, Namely, in these three regions, the use of firewood only for heating is dominant (in Belgrade region 65%, in Central Serbia 59% and in Western Serbia 49.5%).

The majority of households in all selected regions are familiar with the existence of the new types of wood fuels (e.g. wood pellets): in Western Serbia that is 81%, in Central Serbia 88%, in Southern Serbia 79% and in Belgrade region 77% of the interviewed households. However, only 4% of the households from Belgrade region, 2.7% of the households from Western Serbia, 1.7% in Southern Serbia and 1.2% in Central Serbia plan to replace the firewood with new fuels.

2.1.9 Heating systems and characteristics of the heating appliances in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region

The heating systems are one of the most important elements on which the efficiency of consumption, as well as the consumption of wood fuels itself, depend in every household. The results of the conducted survey show that the majority of households from all selected regions use individual heating appliances. The share of households that use individual heating appliances in Southern Serbia amounts to 83%, in Central Serbia 70%, in Western Serbia 65% and in the Belgrade region 55%. The share of households with their own central heating system is the biggest in the Belgrade region 41%, while it is lower in the other three regions: in Western Serbia 31%, in Central Serbia 27%, whereas in Southern Serbia 10% only (fig.9).

The high wood energy consumption in the households in all selected regions could be partially explained by the inefficiency of their combustion, i.e. high share of the households with individual heating appliances. It is known that individual heating appliances are less efficient compared to heating appliances from central heating systems.

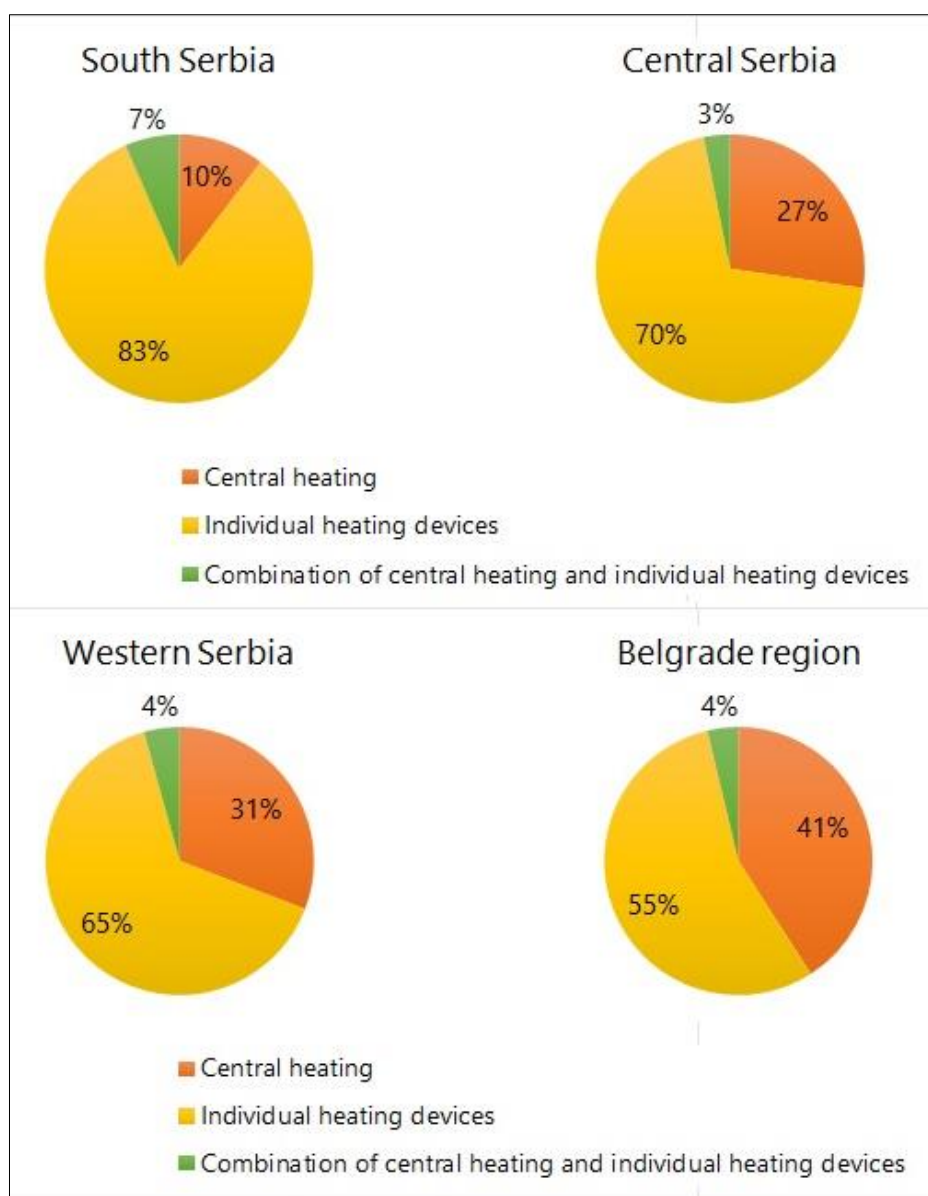


Fig. 9. The presence of particular types of heating systems in the households from Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Besides the heating system, the important firewood consumption and efficiency factor is the age of a heating appliance. According to the survey, 65% of households from Southern Serbia and 56% from Western Serbia possess heating appliances over 10 years old. In Central Serbia and Belgrade region, this share amounts to 46% i.e. 34% respectively (fig. 10). The share of households with up to 5 years old heating appliances amounts to 66% in Belgrade region and 54% in Central Serbia as the best regions.

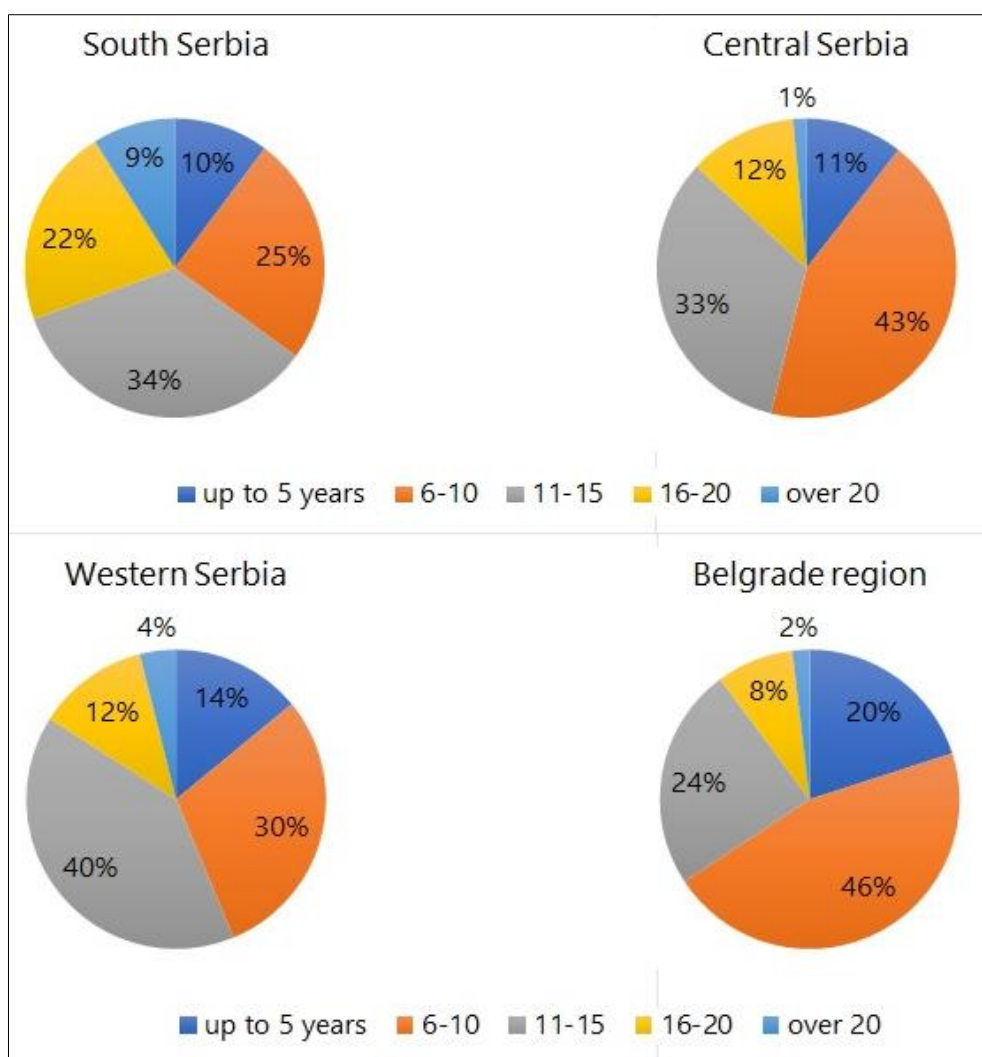


Fig. 10. Frequency of certain age ranges of heating appliances in surveyed households in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Generally speaking, the state of the heating/combusting appliances in households in Southern Serbia and Western Serbia is unsatisfactory, because the share of appliances over 10 years old is big and as such represents one of the key wood energy inefficiency consumption factors.

Regular chimney servicing is also one of the activities which are tightly connected to the efficiency of wood fuels combustion in the heating/combusting appliances, as well as to the wood fuels consumption. Regarding this question, the situation is satisfactory only in Belgrade region where 63% of households regularly service their chimneys every year. In the other three regions, the situation is unsatisfactory. In Southern Serbia, only 28% of the interviewed households regularly service their chimneys every year. In Western Serbia, that share is 40% and in Central Serbia is 41.5%.

2.2 Wood fuels consumption in public and commercial buildings and industry for energy purposes

Wood fuels are an important energy source for a large number of public and commercial buildings in Serbia. According to the results of the research within this project, wood fuels are used in pre-school and school institutions, health institutions, facilities of local administration, commercial buildings and industry.

Total consumption of wood fuels in these facilities in the heating season 2022/2023. is given in Table 11 according to the type of wood fuel.

Table 11. Consumption of wood fuels in public and commercial buildings and industry in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Region	Category of consumers in public sectors	Consumption of wood fuels in the heating season 2022/2023.			
		Firewood [m ³]	Wood chips [tonnes]	Wood pellets [tonnes]	Sawdust [tonnes]
	TOTAL	9,695	0	4,728	72,095
Southern Serbia	Public buildings	6,120	-	3,515	-
	Commercial buildings	3,575	-	1,213	-
	District heating systems	-	-	-	-
	Wood and other industry	-	-	-	72,095
	TOTAL	17,711	7,752	6,253	126,923
Central Serbia	Public buildings	4,967	-	4,429	-
	Commercial buildings	12,744	-	1,824	-
	District heating systems	-	7,752	-	-
	Wood and other industry	-	-	-	126,923
	TOTAL	78,197	21,269	5,337	211,638
Western Serbia	Public buildings	3,679	-	3,646	-
	Commercial buildings	74,518	5,739	1,045	-
	District heating systems	-	15,530	646	-
	Wood and other industry	-	-	-	211,638
	TOTAL	1,483	809	3,873	34,050
Belgrade region	Public buildings	124	809	1,533	-
	Commercial buildings	1,359	-	326	-
	District heating systems	-	-	2,014	-
	Wood and other industry	-	-	-	34,050

Sources: 1. Survey 2023; 2. author's calculations

The most common fuel in wood fuel consumption in public and commercial buildings is firewood in all regions. The total consumption of firewood in these buildings in all regions was 107,086 m³ out of which 78,197 m³ or 73% was consumed in Western Serbia. Such high consumption in Western Serbia is the result of the developed charcoal production. Second place was taken wood pellets with 20,191 tonnes mostly in Central Serbia and Western Serbia.

The district heating systems in Southern Serbia and Belgrade region do not consume wood chips as fuel, whereas the district heating systems in Western Serbia have consumed 15,530 tonnes of wood chips and Central Serbia 7,752 tonnes. In Belgrade regions 2,014 tonnes of wood pellets was consumed in district heating systems.

The wood processing industry in all regions mostly consumes sawdust for energy purposes: in Southern Serbia 72,095 tonnes, in Central Serbia 126,923 tonnes, in Western Serbia 211,638 tonnes while in Belgrade region 34,050 tonnes. There are still no CHP plants installed in these regions.

2.3 Review of the total consumption of wood fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

Based on the implemented research on households, public buildings, commercial buildings, district heating systems, and industry, Table 12 shows the summary presentation of certain wood fuels consumption at the level of each region in heating season 2022/2023.

Table 12. Total wood fuels consumption in Southern Serbia, Central Serbia, Western Serbia and Belgrade region in heating season 2022/2023

Region	Type of fuel				
	Firewood [m ³]	Wood briquettes [tonnes]	Wood pellets [tonnes]	Wood chips [tonnes]	Sawdust [tonnes]
Southern Serbia	1,060,957	28	50,608	-	72,095
Central Serbia	1,403,786	117	70,355	7,752	126,923
Western Serbia	1,260,116	93	69,692	21,269	211,638
Belgrade region	492,037	586	103,784	-	34,859

Sources: 1. Survey 2023; 2. author's calculations

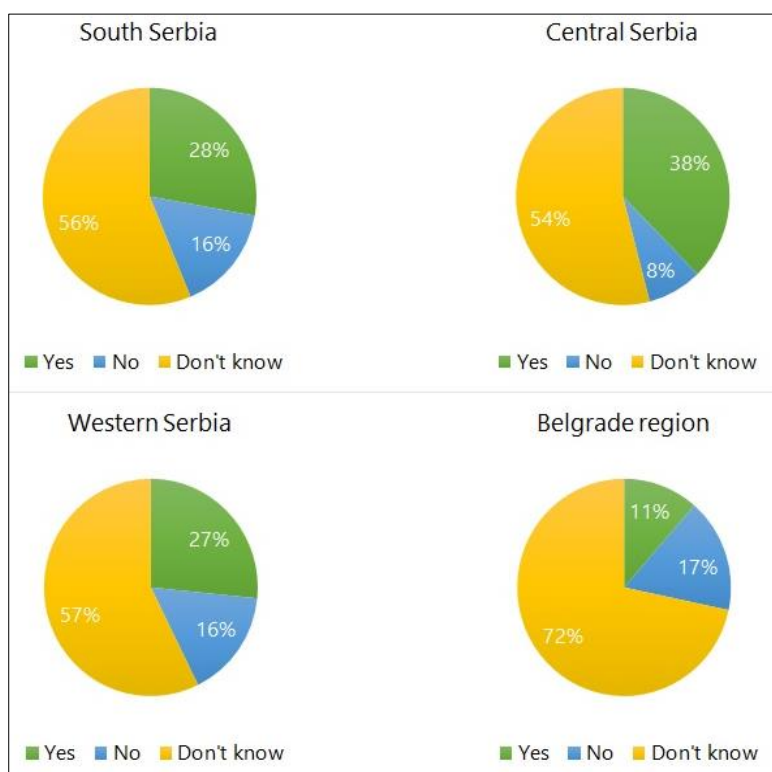
The most common wood fuel for energy purposes in all selected regions is firewood whose consumption in heating season 2022/2023. was 1.06 million m³ in Southern Serbia, 1,40 million m³ in Central Serbia, 1,26 million m³ in Western Serbia and 0,49 million m³ in Belgrade region.

In the second place, there are wood pellets with consumption of almost 51 thousand tonnes in Southern Serbia, 70 thousand tonnes in Central Serbia, almost 70 thousand tonnes in Western Serbia and 103.7 thousand tonnes in Belgrade region.

Since the number of households and the number of public and commercial facilities that consume wood fuels instead of heating oil and/or coal is growing, one may expect that the wood fuels consumption will grow in the following years as well, i.e. that the wood fuels will play a significant role in satisfying the energy needs of these consumer categories in all selected regions.

2.4 The interest of households for planting forests on the abandoned agricultural and other bare lands in Southern Serbia, Central Serbia, Western Serbia and Belgrade region

The abandoned agricultural and other bare land is present in all selected regions. It is both state and privately owned. These lands are mostly used for grazing. Hence, it is possible to use these lands for planting energy forests or energy crops. This would bring lots of benefits for the local (rural) communities and the country as well. Therefore, one of the goals of this project was to examine the interest of the population from the chosen regions for planting forests. Based on this interest, the corresponding measures for planning and support could be proposed to the policymakers.



The first activity in the examination process was discovering whether the local population is familiar with the existence of abandoned agricultural and other bare lands in their municipalities. The results of this survey show that over ½ of the interviewees from all selected regions are not familiar with that (fig.11). In the Belgrade region, 72% of the interviewees are not familiar with that, while the percentage in the other three regions is relatively uniform and amounts from 54% to 57%.

Fig. 11. Awareness of the local population about the existence of abandoned agricultural and other bare lands in the selected regions

Since the share of the population aware of the existence of the abandoned agricultural and other bare lands, the first step in the process of putting these lands into the function of energy crops is informing the people about the possibilities, opportunities and benefits of planting the energy forests or energy crops. This statement is supported by the answers of the interviewees about this topic. Except Western Serbia with 62% in other three regions over 2/3 of interviewees do not know anything about the possibilities of income from forest plantations or energy crops (fig. 12). The percentage of interviewees who are familiar with it is extremely small and ranges from 2% in Southern Serbia to 13% in Western Serbia. The same situation is with interviewees who are only partially informed about this.

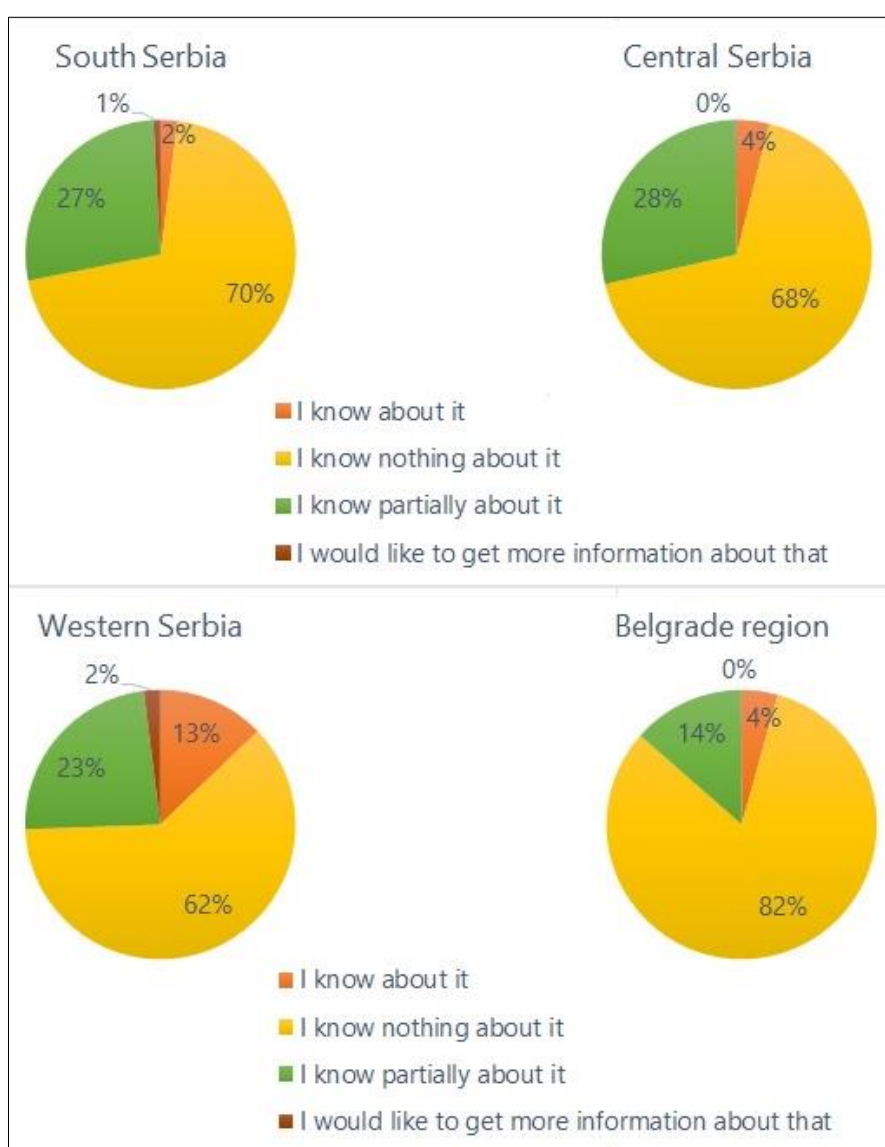


Fig. 12. Awareness of local populations about the possibilities of income from planting forests or energy crops

Regarding the interest of the interviewees in planting the forests on abandoned agricultural and other bare lands, the results of the survey show that currently only 3% of the interviewees from Southern Serbia and Belgrade region and 7% from Western Serbia i.e. 5% in Central Serbia show interest in this process, whereas all other interviewees are not interested or they didn't think about it (fig. 13).

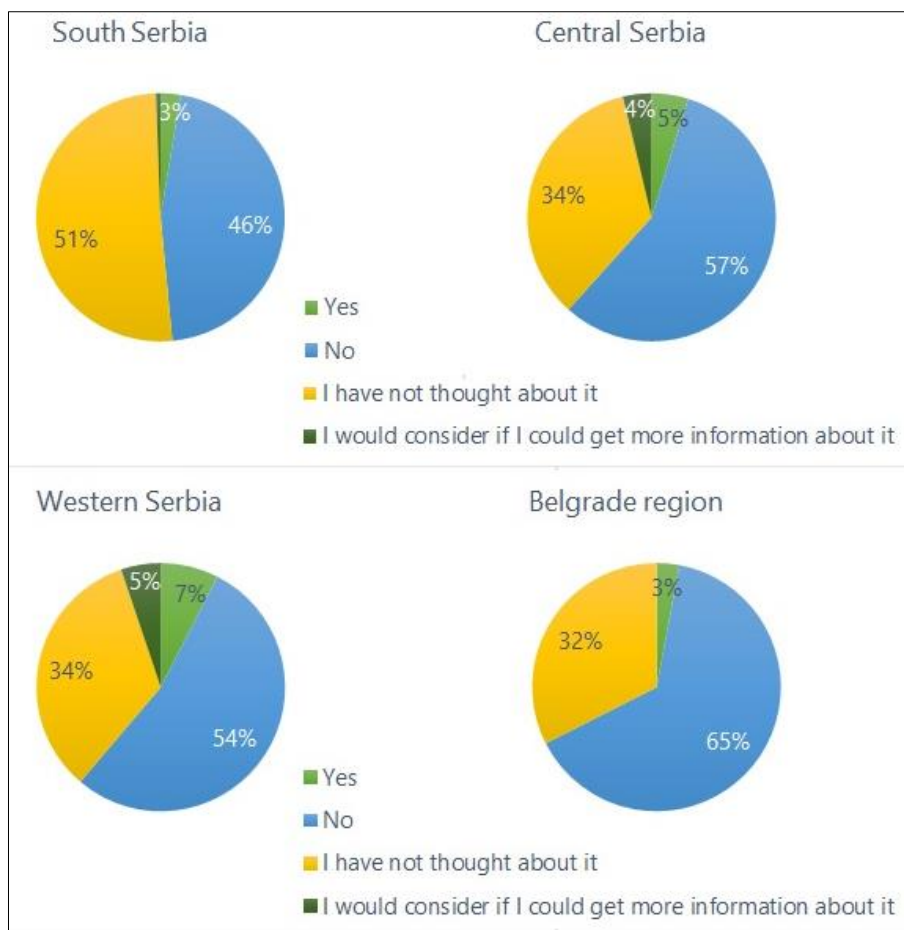


Fig. 13. Results of the survey on the interest of the interviewees for planting forests on abandoned agricultural and other bare lands in the selected regions

Based on the obtained results, one may conclude that situation about the interviewees' awareness of the potential benefits of planting forests on abandoned agricultural and other bare lands is unsatisfactory in all regions. Therefore, it is necessary to work a lot in two directions:

1. Educating the population about the benefits of this process, and
2. Creating and implementing the corresponding supporting measures (by policymakers).

3 BALANCE OF THE GHG EMISSIONS STEMMING FROM THE WOOD FUELS COMBUSTION IN SOUTHERN SERBIA, CENTRAL SERBIA, WESTERN SERBIA AND BELGRADE REGION

This chapter contains the calculation of the GHG emissions stemming from the process of wood fuels combustion by the most important consumers categories. It is based on the methodology adopted and described in chapter 1 of this report and on the consumption of particular wood fuels types from chapter 2. Balancing these GHG emissions was conducted for these four chosen Serbian regions for the first time. The goal was to reveal the exact possibilities of the emission reductions and contributions to the corresponding global efforts of mitigating the adverse climate changes in the sphere of wood fuels consumptions. Although the wood fuels per se are carbon neutral, with the increase of the efficiency of their combustion, one may reduce a lot of GHG emissions and free the additional capacities of the forests to absorb CO₂/GHG stemming from fossil fuels. This efficiency improvement refers primarily to firewood and wood chips because there is a space for optimising the moisture content before combusting them. The GHG emissions are proportional to the moisture content in these two woods fuels types.

Underneath, one may find the GHG emissions balance for all wood fuels consumed for energy purposes in households, public and commercial facilities, district heating systems and industry, separately for each region.

Total CO₂ emissions stemming from the wood fuels combustion in all selected regions during the heating season 2022/2023 are estimated to 5.92 million tonnes (see tables from 13 to 16). Some 80.6% of these emissions stemmed from households (4.77 million tonnes of CO₂), whereas the remaining 19.4% stemmed from all other consumers categories.

The largest CO₂ emissions from wood fuel were realized in the regions of Central Serbia (1.88 million tonnes) and Western Serbia (1.85 million tonnes), while they are slightly less in the region of Southern Serbia in the amount of 1.39 million tonnes. The lowest CO₂ emissions were in the Belgrade region (0.78 million tonnes).

The emissions of nitrous oxide (N₂O) were not that high: in Central Serbia 64.4 tonnes, in Western Serbia 62.2 tonnes, in Southern Serbia 47.1 tonnes and in Belgrade region 27.6 tonnes. The emission of sulfur oxides is symbolically low from wood fuels.

The impact of wood moisture on the emissions of CO₂ was calculated and shown in fig. 14. The calculations were based on wood purchased 6 months before the beginning of the heating season and containing 20% moisture. Based on those emissions, the percentual changes of the CO₂ emissions depending on the time of purchase relative to the beginning of the heating season was derived.

Table 13. Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Southern Serbia during the heating season 2022/2023

Consumers categories	Fuel type	Unit of measure	Timing of purchase of firewood relative to the beginning of the heating season [months]	Approximate moisture content [%]	Net calorific value [MJ per unit]	Consumption in unit of measure	Energy consumption [TJ]	Emission factor [kg/TJ]		Total emissions [tonnes]		
								CO ₂	N ₂ O	CO ₂	N ₂ O	
I. HOUSEHOLDS	Firewood	m ³	12+	18	10671	0	0,0	108619	4	0,0	0,00	
			6	20	10145	0	0,0	109934	4	0,0	0,0	
			5	25	9780	273785	2677,6	113974	4	305178,7	10,7	
			4	30	9647	505327	4874,9	118995	4	580089,1	19,5	
			3	35	9494	221125	2099,4	125446	4	263357,3	8,4	
			2	40	9315	49052	456,9	133553	4	61022,5	1,8	
			1	45	9104	1974	18,0	143880	4	2586,1917	0,1	
			0.5	50	8850	0	0,0	157439	4	0	0,0	
	SUM firewood					1051262	10127			1212233,8	40,5	
	Wood pellets	tonnes		8	17300	45880	794	98303	4	78025,5	3,2	
	Wood briquettes	tonnes		8	17300	28	0	98303	4	47,6	0,0	
		Total households [SUM I]					10921			1290306,8	43,7	
II. Public and commercial buildings and wood industry												
Public buildings	Firewood	m ³	4	30	9647	6120,0	59,0	118995	4	7025,4	0,236	
Public buildings	Wood pellets	tonnes	...	8	17300	3515,0	60,8	98303	4	5977,8	0,243	
Commercial buildings	Wood pellets	tonnes	...	8	17300	1213,0	21,0	98303	4	2062,9	0,084	
Commercial buildings	Firewood	m ³	4	30	9647	3575,0	34,5	118995	4	4103,9	0,138	
Wood industry	Sawdust	tonnes	...	40	9315	72095,0	671,6	133553	4	89689,6	2,686	
District heating systems	Wood chips	tonnes	...	40	9315	0,0	0,0	133553	4	0,0	0,000	
			SUM II					846,9			108859,6	3,4
SUM [III=I+II]							11767,8			1399166,4	47,1	

Sources: 1. Survey 2023; 2. author's calculations

Table 14. Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Central Serbia during the heating season 2022/2023

Consumers categories	Fuel type	Unit of measure	Timing of purchase of firewood relative to the beginning of the heating season [months]	Approximate moisture content [%]	Net calorific value [MJ per unit]	Consumption in unit of measure	Energy consumption [TJ]	Emission factor [kg/TJ]		Total emissions [tonnes]		
								CO ₂	N ₂ O	CO ₂	N ₂ O	
I. HOUSEHOLDS	Firewood	m ³	12+	18	10671	0	0,0	108619	4	0,0	0,00	
			6	20	10145	68596	695,9	109934	4	76503,9	2,8	
			5	25	9780	608042	5946,6	113974	4	677763,7	23,8	
			4	30	9647	497202	4796,5	118995	4	570762,6	19,2	
			3	35	9494	201441	1912,5	125446	4	239913,8	7,6	
			2	40	9315	10794	100,5	133553	4	13428,0	0,4	
			1	45	9104	0	0,0	143880	4	0	0,0	
			0.5	50	8850	0	0,0	157439	4	0	0,0	
	SUM firewood					1386075	13452			1578371,9	53,8	
	Wood pellets	tonnes		8	17300	64102	1109	98303	4	109014,5	4,4	
	Wood briquettes	tonnes		8	17300	117	2	98303	4	199,0	0,0	
		Total households [SUM I]					14563			1687585,4	58,3	
II. Public and commercial buildings and wood industry												
Public buildings	Firewood	m ³	4	30	9647	4967,0	47,9	118995	4	5701,9	0,192	
Public buildings	Wood pellets	tonnes	...	8	17300	4429,0	76,6	98303	4	7532,1	0,306	
Commercial buildings	Wood pellets	tonnes	...	8	17300	1824,0	31,6	98303	4	3102,0	0,126	
Commercial buildings	Firewood	m ³	4	30	9647	12744,0	122,9	118995	4	14629,5	0,492	
Wood industry	Sawdust	tonnes	...	40	9315	126923,0	1182,3	133553	4	157898,3	4,729	
District heating systems	Wood chips	tonnes	...	40	9315	7752,0	72,2	133553	4	9643,8	0,289	
			SUM II					1533,5			198507,5	6,1
SUM [III=I+II]							16096,6			1886093,0	64,4	

Sources: 1.Survey 2023; 2. author's calculations

Table 15. Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Western Serbia during the heating season 2022/2023

Consumers categories	Fuel type	Unit of measure	Timing of purchase of firewood relative to the beginning of the heating season [months]	Approximate moisture content [%]	Net calorific value [MJ per unit]	Consumption in unit of measure	Energy consumption [TJ]	Emission factor [kg/TJ]		Total emissions [tonnes]	
								CO ₂	N ₂ O	CO ₂	N ₂ O
I. HOUSEHOLDS	Firewood	m ³	12+	18	10671	1624	17,3	108619	4	1882,7	0,07
			6	20	10145	15688	159,2	109934	4	17496,6	0,6
			5	25	9780	437327	4277,1	113974	4	487473,7	17,1
			4	30	9647	505659	4878,1	118995	4	580470,8	19,5
			3	35	9494	176456	1675,3	125446	4	210157,2	6,7
			2	40	9315	15764	146,8	133553	4	19611,1	0,6
			1	45	9104	29400	267,7	143880	4	38510,563	1,1
			0.5	50	8850	0	0,0	157439	4	0	0,0
			SUM firewood				1181918,6	11421,4		1355602,7	45,7
	Wood pellets	tonnes		8	17300	64355,0	1113,3	98303	4	109444,8	4,5
	Wood briquettes	tonnes		8	17300	93,0	1,6	98303	4	158,2	0,0
Total households [SUM I]							12536,4			1465205,6	50,1
II. Public and commercial buildings and wood industry											
Public buildings	Firewood	m ³	4	30	9647	3679,0	35,5	118995	4	4223,3	0,142
Public buildings	Wood pellets	tonnes	...	8	17300	3646,0	63,1	98303	4	6200,5	0,252
Commercial buildings	Wood pellets	tonnes	...	8	17300	1045,0	18,1	98303	4	1777,2	0,072
Commercial buildings	Firewood	m ³	4	30	9647	74518,0	718,9	118995	4	85542,8	2,876
Wood industry	Sawdust, solid residues	tonnes	...	40	9315	211638,0	1971,4	133553	4	263287,8	7,886
District heating systems	Wood chips	tonnes	...	40	9315	15530	144,7	133553	4	19320,0	0,579
District heating systems	Wood pellets	tonnes	...	8	17300	646	11,2	98303	4	1098,6	0,045
Commercial and public buildings	Wood chips	tonnes	...	40	9315	5739	53,5	133553	4	7139,6	0,214
SUM II							3016,2			388589,8	12,1
SUM [III=I+II]							15552,6			1853795,5	62,2

Sources: 1.Survey 2023; 2. author's calculations

Table 16. Balance of the GHG emissions stemming from the combustion of wood fuels per consumer category in Belgrade region during the heating season 2022/2023

Consumers categories	Fuel type	Unit of measure	Timing of purchase of firewood relative to the beginning of the heating season [months]	Approximate moisture content [%]	Net calorific value [MJ per unit]	Consumption in unit of measure	Energy consumption [TJ]	Emission factor [kg/TJ]		Total emissions [tonnes]	
								CO ₂	N ₂ O	CO ₂	N ₂ O
I. HOUSEHOLDS	Firewood	m ³	12+	18	10671	0	0,0	108619	4	0,0	0,00
			6	20	10145	8386	85,1	109934	4	9353,2	0,3
			5	25	9780	271396	2654,3	113974	4	302516,5	10,6
			4	30	9647	176216	1700,0	118995	4	202286,5	6,8
			3	35	9494	14954	142,0	125446	4	17810,1	0,6
			2	40	9315	1162	10,8	133553	4	1445,5	0,0
			1	45	9104	18440	167,9	143880	4	24154,279	0,7
			0.5	50	8850	0	0,0	157439	4	0	0,0
	SUM firewood					490554	4760			557566,1	19,0
	Wood pellets	tonnes		8	17300	99911	1728	98303	4	169912,8	6,9
	Wood briquettes	tonnes		8	17300	586	10	98303	4	996,6	0,0
		Total households [SUM I]					6499			728475,6	26,0
II. Public and commercial buildings and wood industry											
Public buildings	Firewood	m ³	4	30	9647	124,0	1,2	118995	4	142,3	0,005
Public buildings	Wood pellets	tonnes	...	8	17300	1533,0	26,5	98303	4	2607,1	0,106
Commercial buildings	Wood pellets	tonnes	...	8	17300	326,0	5,6	98303	4	554,4	0,023
Commercial buildings	Firewood	m ³	4	30	9647	1359,0	13,1	118995	4	1560,1	0,052
Industry	Sawdust and wood chips	tonnes	...	40	9315	34859,0	324,7	133553	4	43366,3	1,299
District heating systems	Wood pellets	tonnes	...	8	17300	2014,0	34,8	98303	4	3425,1	0,139
			SUM II				406,0			51655,2	1,6
SUM [III=I+II]							6904,6			780130,8	27,6

Sources: 1. Survey 2023; 2. author's calculations



Fig.14. Percentual increase/decrease of the GHG emissions from firewood of different moisture content (relative to the purchasing period and derived from the emissions of wood purchased 6 months before the heating season)

How significant the impact of moisture content in the GHG emissions is very well shown by two extreme cases: wood purchased a half month before the beginning of the heating season with the moisture content of approximately 50% emits in the process of combustion 43.2% more GHG compared to the wood purchased 6 months before the beginning of the heating season. On the other hand, the emissions of the GHG from wood purchased 12 and more months before the beginning of the heating season are less by 1.2% compared to the emissions from wood purchased 6 months before the beginning of the heating season.

The values stated in fig. 14 should be considered as the approximate indicators because the wood moisture in the moment of combustion does not depend only on purchasing time, but also on the way and place of storing, climate conditions and technical characteristics of the combusting appliances. The purpose of fig. 14 is to lighten the necessity of education of consumers about the effects of the GHG emissions and to show them how each household can contribute to decreasing the GHG emissions and mitigating the adverse climate changes. The first step in this direction is changing purchasing habits. The consumers should purchase the wood early enough so that they could win enough time for drying and decreasing the moisture content below 30%. The minimum time for reaching this is 6 months before the beginning of the heating season.

The following example illustrates the effects that could be achieved with the mentioned approach: if all consumed firewood in the selected regions had been purchased 6 months before the beginning of the heating season, the total CO₂ emissions stemming from its combustion would be lower by approximately 121 thousand tonnes (compared to total CO₂ emissions from tables 13 to 16). This is a very good illustration of how small changes in the habits of each household could significantly contribute to the efforts of decreasing GHG emissions.

4 CONCLUSIONS AND RECOMMENDATIONS

The most important conclusions related to wood fuels consumption in Southern Serbia, Central Serbia, Western Serbia and Belgrade region are listed below:

- The main characteristic of the wood fuels consumption in the chosen Serbian regions is the dominance of firewood;
- Total consumption of wood fuels for energy purposes in all selected regions in heating season 2022/2023 was the following:
 - firewood 4.2 million m³ ;
 - wood pellets 294,439 tonnes;
 - wood chips 29,021 tonnes;
 - wood briquettes 824 tonnes;
 - sawdust 445,515 tonnes.
- The average consumption of wood energy per 1m² of the heating area in urban households amounts from 185.9 kWh/m² (a) in Belgrade region (as the smallest value) to 278.3 kWh/m² (a) in Southern Serbia (as the largest value). The value of this indicator in other households ranges from 202.1 kWh/m² (a) in Belgrade region (as the smallest value) to 315.7 kWh/m² (a) in Southern Serbia (as the largest value).
- Such high values of the wood energy consumption are unsatisfactory because they are beyond the values of the last class of the energy passport for residential buildings [G class > 188 kWh/m² (a)]. The only exception is urban households in the Belgrade region, whose average consumption per 1m² of heating surface is slightly lower compared to the threshold value of the G class of the energy passport.
- In the last decade, the consumption of firewood grew in Central Serbia by 8.5% and Belgrade region by 20.7% while in Southern Serbia and Western Serbia dropped by 8.4% and 3.0% respectively.
- The consumption of wood pellets had the highest increase in the last ten years in all selected regions but mostly in the Belgrade region where it reached 103 thousand tonnes in 2022.
- The average firewood prices in the heating season 2022/2023 amounted to 58 € per stacked m³ in Southern Serbia to 95.6 € per stacked m³ in Belgrade region. Such a big difference in firewood purchase prices between the two regions arises from the fact that Southern Serbia is the one of the most forested region of the country. Hence, the availability of wood there is significantly larger than in Belgrade region. Firewood prices

in Western Serbia and Central Serbia were relatively uniform and ranged from €70 to €72 per stacked m³.

- The average prices of wood pellets were also uniform in all regions ranged between €295 per tonne in Western Serbia to €357 per tonne in Belgrade region.
- The most important wood fuel supply channels for the households from Southern Serbia, Central Serbia and Western Serbia are their own forests and traders. Together, they supply 76% of the households in Western Serbia i.e. 62% of the households in Southern Serbia and 59% in Central Serbia. In Belgrade region, the supply channels are differentiated. Almost 85% of households provide firewood from two channels: heating fuels warehouses (56%) and from timber traders (29%). The share of state-owned forest as supply channel is symbolic in all regions.
- The majority of households from all selected regions use individual heating appliances. The share of households that use individual heating appliances in Southern Serbia amounts to 83%, in Central Serbia 70%, in Western Serbia 65% and in the Belgrade region 55%. The share of households with their own central heating system is the biggest in the Belgrade region 41%, while it is lower in the other three regions: in Western Serbia 31%, in Central Serbia 27%, whereas in Southern Serbia 10% only

Some 65% of households from Southern Serbia and 56% from Western Serbia possess heating appliances over 10 years old. The situation regarding the heating/combusting appliances in both regions is unsatisfactory since the share of appliances older than 10 years is high. In Central Serbia and Belgrade region, this share amounts to 46% i.e. 34% respectively. The share of households with up to 5 years old heating appliances amounts to 66% in Belgrade region and 54% in Central Serbia as the best regions.

- The most common fuel in wood fuel consumption in public and commercial buildings is firewood in all regions. The total consumption of firewood in these buildings in all regions was 107,086 m³ out of which 78,197 m³ or 73% was consumed in Western Serbia. Such high consumption in Western Serbia is the result of the developed charcoal production. Second place was taken wood pellets with 20,191 tonnes mostly in Central Serbia and Western Serbia.
- Regarding the interest of the interviewees in planting the forests on abandoned agricultural and other bare lands, the results of the survey show that currently only 3% of the interviewees from Southern Serbia and Belgrade region and 7% from Western Serbia i.e. 5% in Central Serbia show interest in this process, whereas all other interviewees are not interested or they didn't think about it.

- Total CO₂ emissions stemming from the wood fuels combustion in all selected regions during the heating season 2022/2023 are estimated to 5.92 million tonnes. Some 80.6% of these emissions stemmed from households (4.77 million tonnes of CO₂), whereas the remaining 19.4% stemmed from all other consumers categories.
- The largest CO₂ emissions from wood fuel were realized in the regions of Central Serbia (1.88 million tonnes) and Western Serbia (1.85 million tonnes), while they are slightly less in the region of Southern Serbia in the amount of 1.39 million tonnes. The lowest CO₂ emissions were in the Belgrade region (0.78 million tonnes).
- The emissions of nitrous oxide (N₂O) were not that high: in Central Serbia 64.4 tonnes, in Western Serbia 62.2 tonnes, in Southern Serbia 47.1 tonnes and in Belgrade region 27.6 tonnes. The emission of sulfur oxides is symbolically low from wood fuels.

Key recommendations

Starting from the results of the analysis of the current situation regarding consumption of wood fuels in Southern Serbia, Central Serbia, Western Serbia and Belgrade region, the most important recommendations for improvement in this area are given below:

- Taking into account that in most supply channels, the offered wood is raw or air-dried for 2-3 months at most, it is recommended to adopt a technical regulation that will set the appropriate rules, control principles, inspection mechanisms and complaints procedures, and that firewood sellers and distributors will have to abide by. Consequently, the sellers will be obliged to sell the firewood with the moisture content of max 30% to final consumers. This will help urban households which purchase wood step by step since they lack storage facilities.
- The education campaign for households and other consumers on the efficient usage of firewood should be conducted because that is very important both for the increase in the efficiency of the firewood usage and for the reduction of GHG emissions and air pollution. The air pollution in most urban areas in Serbia during the heating season has reached warning levels.
- It is necessary to design and conduct an educational campaign about the benefits of the process of planting forests on abandoned agricultural and other bare lands so that the interest of the local populations for that is increased.

- It is necessary to strengthen the capacities of the domestic institutions from the areas of agriculture and energy for understanding the process of planting forests on abandoned agricultural and other bare lands, preparation and adoption of the necessary regulations. Bearing in mind the prominent increase in demand for woody biomass in the last several years and announced investments in district heating systems, the demand for it will continue to grow in the following years as well. Since the capacities of the Serbian forest fund for supplying the biomass for energy purposes have already reached their maximum, the energy plantations and planting new forests represent one of the future sustainable biomass supply channels. The role of the international organisations in this process is important as well.

- When it comes to balancing the GHG emissions stemming from wood fuels consumption, it is necessary to continue working on strengthening the capacities of the institutions charged for environmental protection and monitoring. In this process, the role of international institutions is important as well.

5 USED REFERENCES

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