

ANALIZA KORIŠĆENJA RAZLIČITIH ENERGENATA U DOMAĆINSTVIMA U SRBIJI

ANALYSIS OF THE VARIOUS ENERGY SOURCES USAGE IN THE HOUSEHOLDS IN SERBIA

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Sektor domaćinstva spada u velike korisnike energije. Preko 30 procenata finalne energije u Srbiji koristi se u ovom sektoru. U ovom radu prikazana je analiza korišćenja energije u domaćinstvima u Srbiji za vremenski period od 10 godina. U analizi su korišćeni relevantni statistički podaci o potrošnji različitih energenata između 2012. i 2021. godine. Za svaki od njih prikazana je struktura korišćenja finalne energije prema nameni u domaćinstvima, određene su vrednosti energije koja se predaje krajnjim korisnicima, kao i ukupno korišćena primarna energija. Analizirane su jedinične cene primarne, finalne i korisne energije za svaki od energenata korišćenih u domaćinstvima, što predstavlja polaznu osnovu pri određivanju strategije razvoja energetike u ovom sektoru.

Ključne reči: *energenti; korišćenje energije; cena energije; domaćinstva u Srbiji*

The household sector is one of the major users of energy. Over 30 percent of the final energy in Serbia is used in this sector. This paper presents an analysis of energy use in households in Serbia for a period of 10 years. Relevant statistical data on the consumption of various energy sources between 2012. and 2021. were used in the analysis. For each of them, the structure of final energy use according to purpose in the households is shown, the values of the energy delivered to the end-users, as well as the total primary energy used, are determined. The unit prices of primary, final and useful energy for each of the energy sources used in households were analyzed, which is the starting point for determining the energy development strategy in this sector.

Keywords: *energy sources; energy use; price of energy; households in Serbia*

1 Introduction

Energy represents one of the pillars of every state. It is the main driver of the entire economy. The economy uses huge amounts of energy, and thus energy sources. However, it is not only the economy that is a big user of energy. Besides it, the main users of energy are households. Analysis of final energy use in EU countries conducted in 2021 reveals three dominant sectors: transport (29.2%), households (27.9%) and industry (25.6%) [1]. In the period from 2007 to 2021, in the industry and transport sectors, there was a decrease in the final energy use of 12.4% and 5.8%, respectively. In contrast to these, in the household sector in the same period, there was an increase in the final energy use by 5%.

The European countries with the highest average share of final energy in the household sector in the period from 1998 to 2015 were: Croatia (37.99%), Latvia (36.66%), Hungary (35.44%), Estonia (33.88%), Lithuania (32.51%) and Poland (32.34%) [2]. In Romania, a large part of final energy was also used in households (33.90%), but in its case, a slightly larger part of final energy was used in industry (36.43%). On the other hand, the countries with the lowest average value of the share of final energy in the household sector, in the given period, were: Luxembourg (12.87%), Cyprus (15.19%), Portugal (16.59%), Spain (16.71%), Malta (17.12%), Finland (20.39%) and the Netherlands (20.75%) [2].

The relevant official data on an annual basis on the consumption of energy sources in Serbia is provided by its Republic Statistical Office (RSSO). In Serbia, the sectors of industry, transport and households also represent the sectors in which the most final energy is used. In 2007, the largest part of final energy was used in industry 35.2%, in households 27.4%, and in the transport sector 22.3%. Five years after that, in 2012, the industry and household sectors were almost equal in this aspect (industry 31.2%, households 31%). Since 2013, Serbia can also be counted among the countries where the most final energy is used in households, and the amount of that energy is continuously increasing. The distribution of final energy used by all sectors in Serbia, in the period from 2007 to 2021, determined on the basis of RSSO data [3], is shown in Figure 1.

The diagram clearly shows that the household sector has become the dominant sector in terms of final energy use in Serbia. The share of energy used in households was 38.2% in 2021, while in traffic it was 26.8%, and in the industry only 22.4%. As approximately 40% of the energy is used in households, it is necessary to make a comprehensive analysis from the point of view of energy consumption and prices.

This paper provides an overview of the final energy used in households in Serbia for the period 2012-2021. The structure of the used final energy according to its purpose is shown. The values of the useful energy delivered to the end-users and the total primary energy of each energy source is shown. Changes in the final energy prices of all energy

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sources in the analyzed ten-year time period is shown. The unit prices of primary, final and useful energy have been determined. A proposal for the price formation of all energy sources is given, which is based on the equal monetary value of their primary energy.

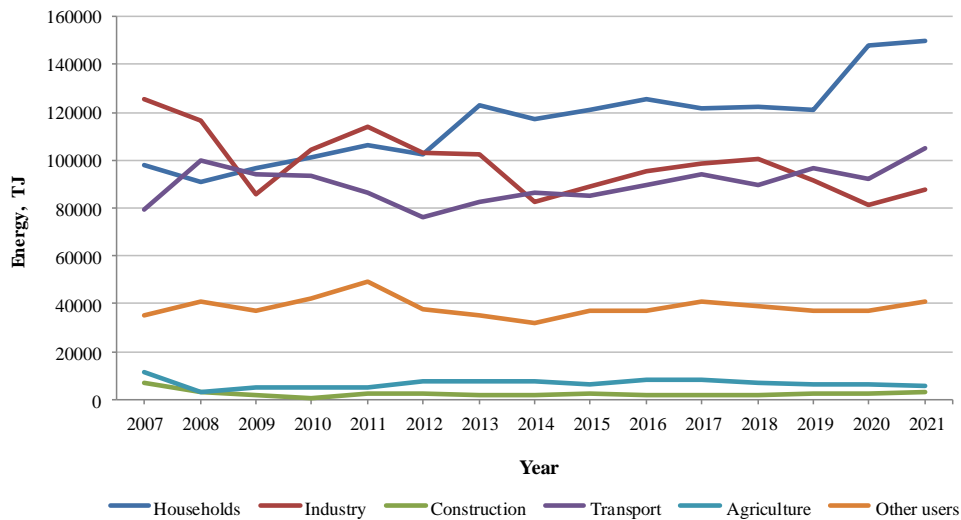


Figure 1. Final energy use by sectors in Serbia

2 Statistics of various energy sources consumption in households in Serbia

To meet the needs of households in Serbia, the following are used: electricity, derived heat, coal, oil derivatives, natural gas and wood fuel. In 2012, heating oil, fuel oil and liquid petroleum gas (LPG) were used as petroleum derivatives. The share of fuel and heating oil was not negligible, it was 45%. However, in the following two years, it dropped to around 10%. Since 2015, LPG has become the only oil derivative used in households. When it comes to coal, brown coal and lignite and their briquettes are used in households. Firewood, wood briquettes, wood pellets and formerly charcoal are used as wood fuels. Firewood is used in the largest percentage. In the period from 2013-2015, that percentage was over 99%. Since 2017, wood pellets have been used more intensively. Their share in the total wood fuel consumption increased to close to 5%. In addition to them, wood briquettes are also used, but in an amount of less than half a percent. Charcoal consumption practically stopped in households in 2016.

2.1 Use of final energy in households

The analysis of the final energy use in households in Serbia was conducted for the ten-year period from 2012 to 2021. Before this period, a complete overview of wood fuel consumption was not available. At that time, statistical data included only the use of firewood for energy purposes. The overall view of the final energy use in households from 2012-2021, based on RSSO data [3], is shown in Figure 2.

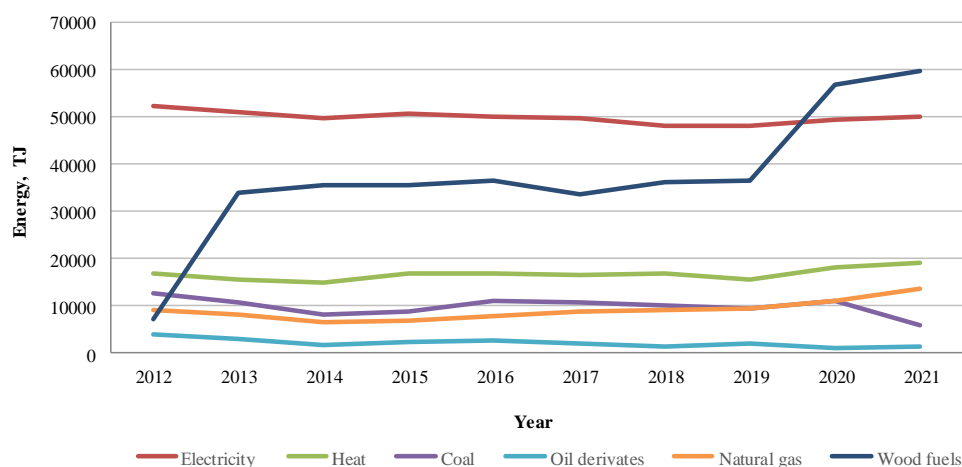


Figure 2. Final energy use in households in Serbia

Based on the analysis of the diagrams shown in Figures 1 and 2, and taking into account the total used final energy of various energy sources on the territory of Serbia, it can be concluded that in the period from 2012 to 2021:

- The amount of electricity used in households has an approximately constant value. Until 2019, it was the dominant type of energy used. Households use less and less electricity to meet their energy needs. Its share

- in the total used energy in households decreased from 51% in 2012 to 33% in 2021. The share of electricity in the total used electricity in the territory of Serbia is also decreasing - in 2012 it was 54%, while in 2021 was 48%. This is a consequence of the fact that the total energy used in households is growing at a high rate.
- In 2020, the energy obtained by transforming wood fuels became the most used form of energy in households in Serbia. Its share in the total energy used in households increased from 7% in 2012 to 40% in 2021. Based on the comparison with the total used energy obtained from wood fuels in Serbia, we come to the conclusion that in 2012, 69% of that energy was used in households, while in 2021, that share increased to as much as 88%.
 - The use of energy obtained from natural gas in households has a constant slight growth. The share of energy from natural gas in households in the total used energy from natural gas in Serbia increased from 17% in 2013 to nearly 30% in 2021, while its share in the total energy used in households in 2021 was approximately 10%.
 - The use of derived heat in households in Serbia is not insignificant. Its share in the total energy use in households ranged from 12% to 17%, with that share decreasing from year to year. On the other hand, the share of the derived heat in households in its total use on the territory of Serbia has a slight tendency to increase. It fluctuated between 52% and close to 60% of what it was in 2021.
 - In households, there was a decrease in the energy use obtained from coal. The share of this energy in the total energy used in households in 2012 was 13%, while in 2021 it was only 4%. However, on the other hand, the share of this energy in the total used energy obtained from coal in Serbia shows a growing tendency. It changed significantly over the years and ranged from 32% in 2015 to 54% in 2019, while in 2021 it was 48%.
 - The use of energy obtained from petroleum derivatives in households is constantly decreasing. The share of this energy in the total energy used in households and in the total energy obtained from oil and oil derivatives in Serbia decreased from 4% to about 1%.

2.2 Energy consumption structure in households

Energy is used in households for various purposes: space heating and cooling, water heating, cooking, powering electrical appliances and lighting. The energy use in households in Serbia changes on an annual basis. This is due to many factors. The main influence, in addition to energy properties, is the price and availability of energy sources on the market. Relevant statistical data on the energy use structure in households in European countries is provided by the EU Statistical Office (Eurostat). Based on data related to the calendar year 2021 [4], Figure 3 shows the structure of final energy use in households in Serbia. From the figure we can conclude that the most energy is used for space heating (66.1%), followed by powering electrical appliances and lighting (14.4%), water heating (11.9%), cooking (7.2%) and space cooling (0.4%). In the EU, energy is used for the same purposes in households and in approximate percentages (space heating 64.4%, water heating 14.5%, powering electrical appliances and lighting 13.6%, cooking 6%, space cooling 0.5% and other purposes 1.1%).

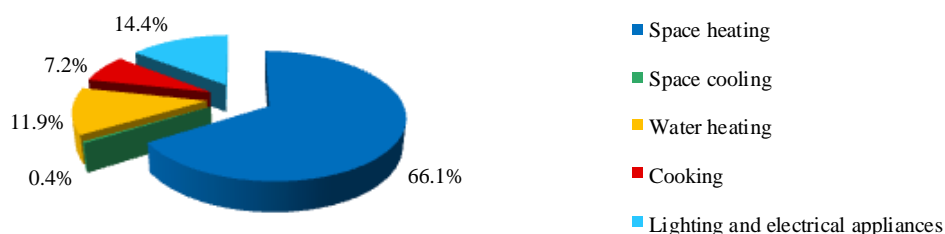


Figure 3. Structure of final energy use in households in Serbia

In a large number of European countries, most of the final energy in households is used for space heating. This share in 2021 was the highest in Luxembourg (80.3%), Slovakia (74.6%), Belgium (74.4%), Hungary (72.8%), Bosnia and Herzegovina (72.7%), Estonia (71.1%), North Macedonia (69.9%), Austria (69.6%) and the Czech Republic (69.4%) [4]. On the other hand, the smallest part of energy for space heating was used by Malta (22.5%), Portugal (30.8%) and Cyprus (34.8%).

The structure of the various energy sources used for space heating in households in Serbia in 2021, determined on the basis of available data [4], is shown in Figure 4.

Serbia belongs to the countries that get more than 50% of the energy needed for heating their homes from renewable energy sources. In Europe, these are: Portugal (87.3%), Bosnia and Herzegovina (83%), Croatia (65%), Moldova (60.5%), Bulgaria (55.7%), Slovenia (59.9%), Romania (51.3%) and Estonia (50.3%) [4]. In Serbia, the highest amount of energy needed for space heating is obtained from wood fuels (56%), followed by derived heat (19.1%) and energy from natural gas (11.7%). The shares of electricity and energy obtained from coal, which are used for heating, are almost equal and amount to 6%, while the smallest share of energy, 1%, is obtained from LPG.

The consumption structure of each energy source, according to its purpose in households in Serbia, is given in Figure 5. The size ζ defines how many percent of the final energy obtained from a certain energy source is used for the purposes it has in the households.

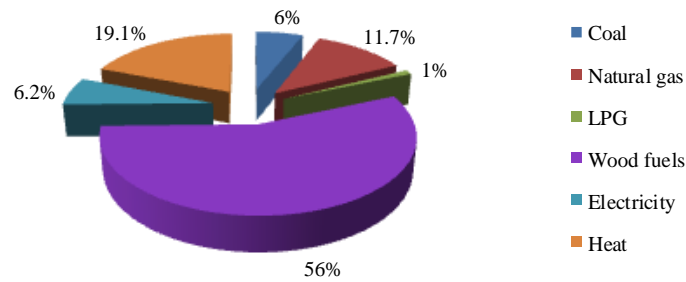


Figure 4. Energy consumption structure for space heating in households in Serbia

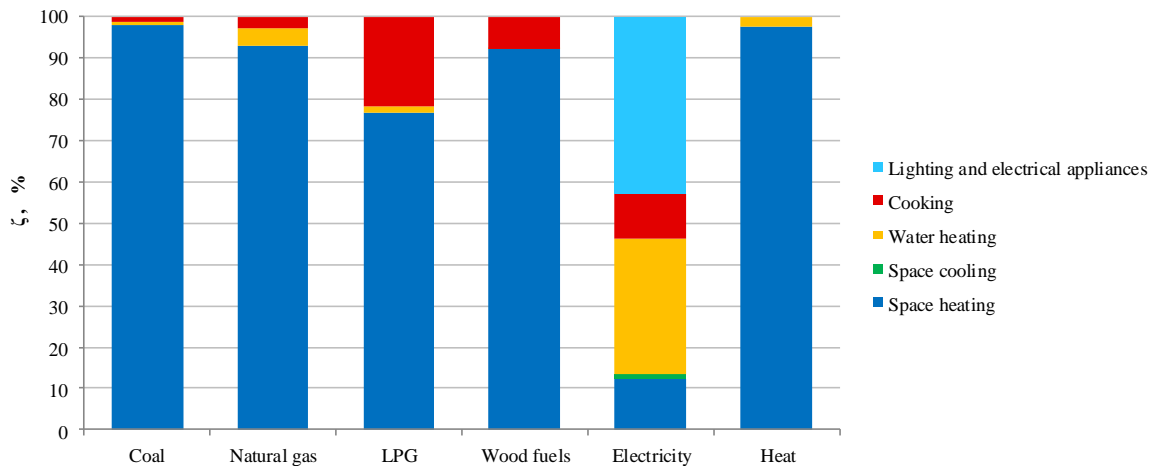


Figure 5. Structure of energy source consumption by purpose in households in Serbia

All energy sources, with the exception of electricity, are mostly used for space heating. Four of them (coal, natural gas, LPG and wood fuels) are used for the same purposes. Coal is primarily used for space heating (97.9%), followed by cooking (1.2%) and water heating (0.9%). Natural gas and wood fuels are used in approximately equal percentages for space heating (natural gas 92.9%, wood fuels 92.1%). In addition, 4.4% of energy obtained from gas is used for heating water, while 2.7% is used for cooking, while 7.7% of energy from wood fuels is used for cooking, and only 0.2% is used for water heating. When it comes to energy obtained from LPG, 76.8% is used for space heating, 21.8% for cooking, and 1.4% for water heating. Derived heat is used for two purposes - space heating (97.4%) and water heating (2.6%). The purposes of electricity in households in Serbia are more diverse. Given that electricity is the only energy source for powering electrical appliances and lighting, the largest part of it is used for powering them (42.9%). In addition, 32.9% of electricity is used for water heating, 12.2% for space heating, 10.8% for cooking and 1.2% for space cooling.

2.3 Flows of energy used in households

Based on the final energy balance, primary energy and useful energy used in households in Serbia were determined. The definition of all three forms of energy is shown in Table 1.

Table 1. Primary energy, final energy and useful energy

Term	Definition	Type of energy or energy source
Primary energy (E_{prim})	Energy found in nature, which is not subjected to any transformation process	e.g. chemical potential of fossil or wood fuels, nuclear energy, renewable energy sources (wind energy, water flow energy, thermal energy of geothermal sources, energy of direct solar radiation, etc.)
Final energy (E_{fin})	Energy delivered to the end-user's household boundary	e.g. natural gas, oil derivatives, electricity, thermal (internal) energy of water or steam
Useful energy (E_{use})	Energy that the end user directly uses in the form that suits him	e.g. light energy, amount of heat given off by radiators, mechanical work to drive the appliances

Primary energy is determined for each of the energy sources. Primary energy differs from final energy by the value of the primary energy conversion factor of the given energy source f_p [5]:

$$E_{\text{prim}} = f_p \cdot E_{\text{fin}} \quad (1)$$

In order to determine the useful energy that is directly used in households, it is necessary to know the value of the efficiency (η) for each device, i.e. every process. As it defines the degree of "utilization" of energy, i.e. the efficiency of converting final energy into the desired form of useful energy, it is valid that:

$$E_{\text{use},i} = \eta_i \cdot \zeta_i \cdot E_{\text{fin}} \quad (2)$$

Applying equation (2) determines the useful energy obtained from a certain energy source, when it is used for its i -th purpose in the households. By adding up the values for all purposes that the energy source has, the total useful energy obtained by its transformation is determined.

The efficiencies of various heating systems are determined by calculation [5], taking into account the type of energy source, as well as the characteristics of the working equipment. The efficiencies of various devices for heating water and cooking, as well as efficiencies of electrical appliances and lighting, were adopted empirically [6,7].

3 Prices of final energy in households in Serbia

Energy prices are determined by the market. Based on the conducted market research [8-10], the dynamics of energy source prices on the territory of Serbia, in the period from 2012 to 2021, were established. The results of the research are shown in Figure 6. During the analysis, the assumption that households in Serbia have built-in two-tariff meters was adopted. When determining the price of derived heat, the differences in prices for space heating and water heating were taken into account. When it comes to wood fuels, their average price was formed based on the price movement of firewood and wood pellets.

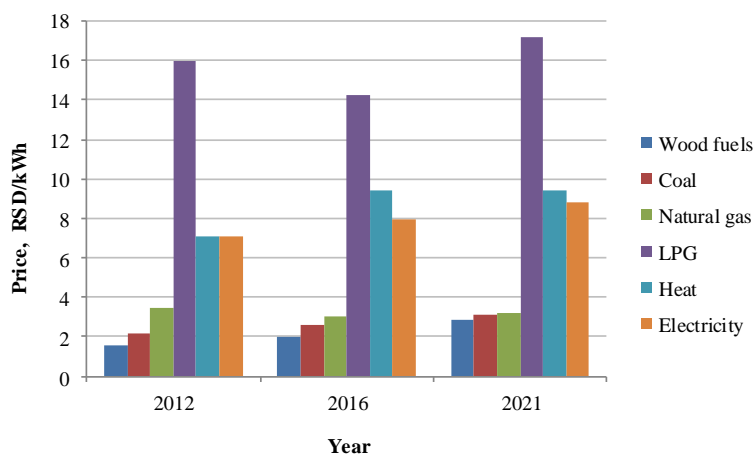


Figure 6. Prices of final energy in households in Serbia

One group of energy sources, which includes wood fuels, coal, derived heat and electricity, shows a constant increase in the price of the final energy obtained from them. The prices of natural gas and LPG fluctuated in the observed period. The price of final energy obtained from LPG has the highest value, followed by the price of derived heat and electricity. The prices of natural gas, coal and wood fuel have lower values. There is a noticeable decrease in the price difference between these energy sources.

4 Results

Due to large variations in the value of the final energy used in households, the types of energy used, their consumption structure and prices, the analysis was conducted on the basis of data for the year 2021. In this way, the current authoritative indicators of energy consumption in households in Serbia were obtained.

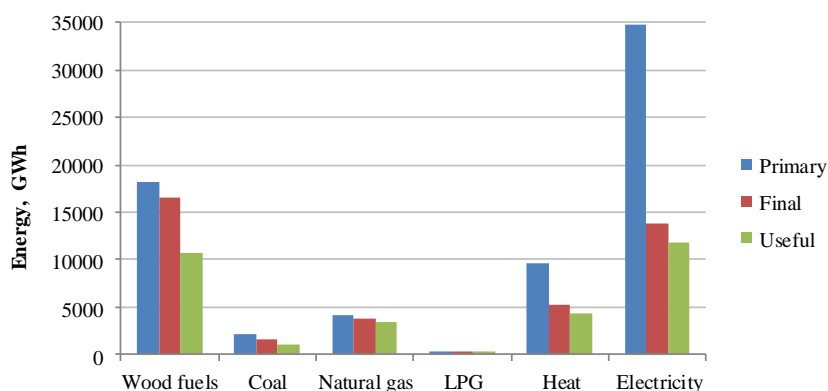


Figure 7. Flow of used energy in households for various energy sources

The flow of energy used in households, for all energy sources, is shown in Figure 7. Based on the known value of the final energy obtained from energy sources, their primary and useful energy was determined. The energy flow diagram provides clear information about the efficiency of energy transformation for a given source. In households, most of the final energy is obtained from wood fuels (40.2%), followed by final electrical energy (33.6%). However, the diagram clearly shows that the primary energy of wood is lower. Primary energy values depend on the primary energy conversion factor of a given type of fuel and it is the highest for electricity [5]. Losses of primary energy during the process of transforming fossil fuels into electricity are the greatest. Therefore, from the energy aspect, electricity is the most unfavourable energy source in households. This refers primarily to space heating because for some other purposes in households, electricity is irreplaceable. Derived heat is also obtained in Serbia through the transformation of fossil fuels, which is why the difference between primary and final energy is significant. From the energy point of view, the most favourable energy source for use in households is natural gas. On the one hand, it is a consequence of its small conversion factor, due to which the difference between primary and final energy is the smallest. On the other hand, due to the high energy efficiency of processes and devices that use natural gas in households, there is little difference between the final energy and the energy delivered to end-users.

The energy flow diagram in household heating, for each of the energy sources, is shown in Figure 8. A small difference between the final and useful electrical energy indicates the high efficiency of space heating systems that operate using this energy source. After these, natural gas heating systems follow in order of efficiency, then district heating systems, then systems that use LPG, wood fuel and finally coal.

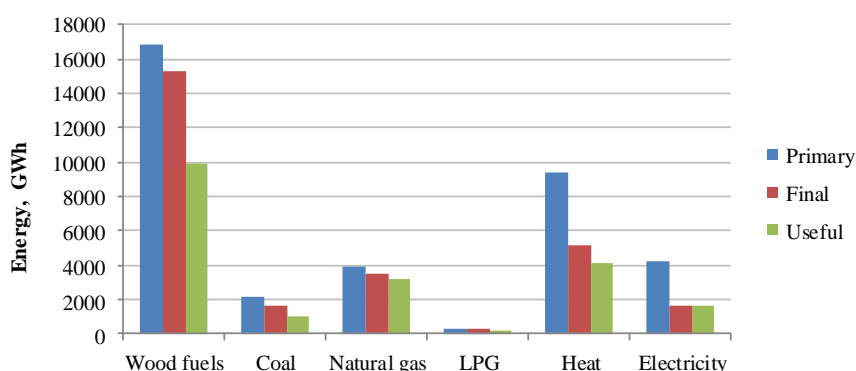


Figure 8. Flow of used energy in household heating for various energy sources

Figure 9 shows the prices of energy used in households, for each of the energy sources, in [RSD/kWh]. From the diagram, we clearly see the big differences in the prices of primary energy, final energy and useful energy. The most uniform prices of all energy forms are the prices of natural gas. Based on the comparison of various energy sources, LPG leads the way in prices, followed by derived heat and electricity.

From a thermodynamic point of view, the prices of primary energy of all energy sources should be mutually equal. The analysis was carried out under the assumption that they have a price equal to the average primary energy price of all energy sources used in households. The ratio of the current prices of energy sources and the prices they would have if this price parity were established is shown in Figure 10. The figure also shows the ratio of primary and useful energy of energy sources.

According to the adopted primary energy price parity, looking at the results, we can conclude that the current LPG and derived heat prices are higher than recommended. The price of primary electricity has a recommended value. In contrast, the prices of natural gas, wood fuels and coal in primary form, according to purely thermodynamic criteria, should be higher by 17%, 26% and 32%, respectively.

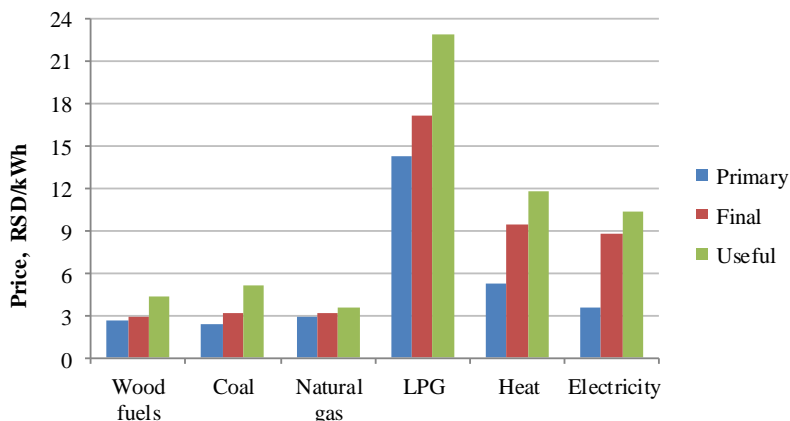


Figure 9. Prices of energy (primary, final, useful) in households in Serbia

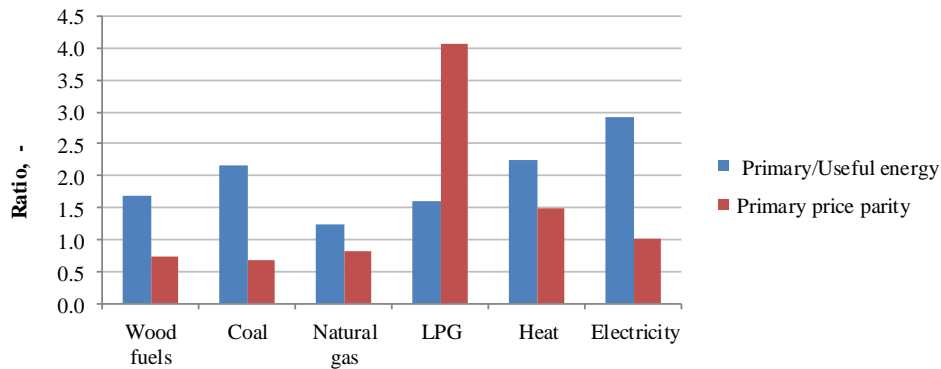


Figure 10. Parity of energy prices in households in Serbia

5 Conclusion

The aim of this work was to show the trends in the use of various energy sources in households in Serbia. The analysis was conducted on the basis of relevant official data on energy consumption in the ten-year period from 2012-2021. Based on the conducted analysis, it was concluded that the energy obtained by the transformation of wood fuels has become the most used form of energy in households in Serbia, with a tendency for its further growth. The use of derived heat and energy obtained from natural gas also shows constant slight growth. The amount of electricity used in households has an approximately constant value. Energy obtained from coal and oil derivatives is used less and less in households.

Based on the structure of final energy use according to its purpose, it was shown that the most energy is used for space heating needs, 66.1%. Electricity used for powering electrical appliances and lighting is 14.4%, the share used for heating water is 11.9%, while 7.2% of the energy used by households is used for cooking. The structure of energy consumption for space heating shows that as much as 56% of the required final energy is obtained from wood fuels. It is followed by derived heat at 19.1%, natural gas energy at 11.7%, electricity at 6.2% and energy obtained from coal at 6%.

The analysis showed that the current prices of energy sources used in households in Serbia do not support the position on the equality of their primary energy prices.

The conducted analysis is a starting point for the purpose of defining an energy policy whose recommendations should lead to improvement of energy efficiency, rational use of energy and use of RES for own needs in the households. The end result would be more efficient energy use in the sector, which at the moment uses close to 40% of the total final energy in Serbia.

6 Acknowledgement

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