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Analysis of the development of energy consumption of electricity and fuels in Slovakia

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Abstract
As the standard of living rises, the energy consumption of electricity and fuels increases not only in Slovakia but across the European Union. Future energy demand will be based on population growth, and it is the key factor of economic and social development of the society, with an emphasis being put on improving the quality of life. This study focused on the development of the final energy consumption (FEC) of individual fuels, electricity and heat, including their shares in the final energy consumption in selected economy sectors in Slovakia. Time-series analysis methods were applied to predict energy consumption for the next three years. Although we have witnessed a decrease in the total energy consumption in individual sectors in Slovakia in the years 2005–2015, energy consumption generally exhibits an increasing trend. In all of the analysed sectors, the development of final consumption of energy from renewable energy sources (RESs) and wastes exhibited a rising trend; nevertheless, the results of our evaluation indicated that Slovakia still has some major shortcomings as to the utilisation of RESs.

Keywords
energy, energy consumption of electricity and fuels, consumption development and forecasting

Introduction

At present, consumption of energy and fuels, as well as access to energy sources, represent the issues that are most intensively discussed in many countries as a result of the current global situation and an increasing pressure aimed at ensuring sufficient amounts of energy materials that are crucial for smooth economy growth (Skare et al. 2023). Ascertaining access to strategic energy materials has become a utilitarian task of every country that aims to ensure the stability of its entire economy. That is why many countries strive to create various programs and strategies aimed at increasing the rate of utilisation of domestic sources, renewable energy sources, or through diversification of supplies from other countries (Mata Pérez et al., 2019). A similar conclusion may be found in the paper (Demski et al., 2018), according to which the countries where there are increasing concerns among the public regarding the dependency on exported energies and their prices may eventually lead to the development of efficient strategies that might mitigate such concerns.

In the European Union, the issues regarding energy supplies currently become part of the key priorities that affect its political, economic and social life (Androniceanu, 2023; Androniceanu & Georgescu, 2023). Slovakia is no exception to this since it greatly depends on importing strategic energy materials from other countries (primarily from the Russian Federation), which makes it one of the most vulnerable European countries in case of an energy crisis (Integrated National Energy, 2019). This is currently affected by multiple internal as well as external factors—high costs of energy materials on global markets and relatively limited reserves of such materials in the EU countries; the need to decommission obsolete production capacities and replace them with new ones; a constant growth of the overall demand for energies and increasing energy consumption; and increasing requirements for energy transport and distribution (Riaz et al. 2023; Komasi et al. 2023). According to the paper (Energy prices crisis, 2022), such a combination of extreme price instability prices and individual contract schemes exposes millions of EU citizens to the risk of poverty while further deepening the uncertainty that has already become omnipresent. The utilisation of renewable sources is developing worldwide, although at varied rates (Simionescu et al. 2021, 2022). While in some regions, fossil sources of electricity are actually being replaced with new renewable sources, in other regions production of electricity from coal and other fossil sources is still increasing since their capacities of renewable sources are not sufficient enough to cover the increasing demand (Šoltés & Gavurova, 2014; Ahmad et al. 2022). Many studies and articles have been published on various methods of energy production and utilisation, offering various methods for using other (renewable) energy sources. According to the paper (Värri & Syri, 2019), practically in all countries of the world, there are efforts to reduce energy production from fossil sources and replace them with renewable energy sources. The countries that are leaders in the implementation of higher targets in the field of renewable energy include Finland, Sweden, Denmark, Germany, Austria, Netherlands and Belgium (State of Renewable Energies, 2018). They are driven by their concerns regarding the environment and by their economic interests, and their efforts are reflected in their large shares in the submitted European and global patents for sustainable technologies and in their revenues from green technologies. The authors of the paper (Cekinir et al., 2022) offered a manual for the preparation of Turkey's energy policy, according to which Turkey might satisfy its energy needs by using exclusively its own sources. Their forecasts were made using an artificial neural network model in MATLAB. Replacing coal mining with the utilisation of renewable energy sources in northern China was discussed in the study (Ampah et al., 2022). The authors proposed various solutions comprising solar photovoltaic systems, wind turbines, and diesel generators to be used for the excavation and transport of the recovered coal. Data optimisation and simulation in a repeated analysis were used by the authors of the paper (Gaure & Golombek, 2022) to show how the EU may design the electricity production sector without CO_2 emissions by using wind and solar photovoltaic electricity and the energy storage technology. According to the paper (Kannaiyan & Bokde, 2022), the production of electricity from solar energy has become much desired since it is widely accessible and environmentally friendly.

Over the past years, a lack of knowledge of optimal energy utilisation has led to a significant increase in the demand for energy compared to the quantity of energy produced. Power companies have offered various plans to solve this problem, such as regulating consumption in households (Razmjooy et al., 2021). A very similar topic was discussed by the authors of the paper (Miletić et al., 2022). The development of renewable energy sources and combined heat and power (CHP) production, together with the use of controllable electrical appliances, have brought new possibilities for planning energy sources and consumption in smart houses (Ghayour & Barforoushi, 2022; Krmela & Šimberová, 2023). The study (Vengosh & Weinthal, 2022) evaluated the reduction of the water footprint of the power industry in the USA on the national level, as well as the expected virtual water footprint of individual houses after the transition to energy generated by roof-integrated photovoltaic solar systems and wind energy. Photovoltaic systems installed on roofs may contribute to eliminating the problem of increasing demand for electricity and concurrently satisfy the demand for environmentally sustainable power systems (Qadourah et al., 2022). Generating wind energy in offshore wind turbines contributes to decarbonising the power system. Study (Chen et al., 2022) applied a life cycle analysis (LCA) to the evaluation of the potential environmental impact of the first Chinese prototype of a high-performance wind farm. Paper (Maione et al., 2022) proposed a sustainable medium-enthalpy geothermal system in the Campania region in southern Italy, capable of producing electric and

heat energy with only a low environmental impact. Depression in the utilisation of black and brown coal and natural gas in thermal power stations should soon be compensated by biomass combustion. In the article (Sirisomboon et al., 2023), the authors investigated operational problems that occur in electricity production in power stations using biomass in northern Thailand. In the article (Vargas-Soplín et al., 2022), the authors described potential methods for using tree leaves to produce biogas as an alternative energy source.

Authors (Komarova et al., 2022) investigated the correlation between economic growth and the level of energy consumption in various countries that were divided into groups according to their economic development levels and geographical locations. According to this study, the development of the global power market exhibits uneven energy consumption based on different economic development levels and different levels of infrastructure and population (Table 2). According to (Pavlicko et al., 2022), accurate forecasting of power consumption plays a key role in a policy for power supplies while there is a need to ensure a constant balance between the power consumed and the power produced. In this article, the authors discussed models for forecasting the production of maximum hourly electricity consumption per day in Slovakia. Renewable energy sources and energy efficiency in Slovakia and the Czech Republic are discussed in the article (Brozyna et al., 2020).

The present article deals with a survey on the development of final energy consumption (FEC) of individual fuels, electricity and heat, including their shares in the total FEC in a given year, development of final energy consumption in selected economy sectors in the Slovak Republic (Industry, Transport, Agriculture, Trade and Services, and Households), as well as their shares in the total FEC in a given year. Methods of a time-series analysis were applied to predict energy consumption for the period of the next three years.

Material and methods

Energy sources in Slovakia

Slovakia (the Slovak Republic) is a landlocked country in Central Europe (Fig. 1), a member of the European Union since 2004. The territory with a total area of 49,035 km² is populated by approximately 5.45 million inhabitants. Bratislava is the capital city.

Fig. 1. Slovakia and its neighbouring countries

Slovakia is a country with low reserves of primary energy sources. Its domestic sources of fossil fuels are brown coal and lignite. As to liquid and gas energy sources, domestic production represents only about 4%. Slovakia ranks among the countries with high import dependency, approximately 65% (Jandacka et al., 2022). Over the past years, we have also become dependent on imported electricity, primarily from the Czech Republic and Austria.

Electricity has a special place among energy sources; this is contributable to the fact that the growth of its production and consumption does not necessarily have to be accompanied by a negative impact on the environment, as is the case with the other types of fuels and energies. Electric energy may be regarded as clean when produced and consumed with high efficiency, when substituting energy production by combustion of low-energy fuels, or when produced from renewable energy sources. Over the past years, consumption of renewable energy sources (RESs, wastes and electricity produced in hydroelectric power plants) has gradually increased, and in 2020 its share represented approximately 14.4%. Dominant positions were held by biomass and hydroelectric energy. Increasing the share of RESs is very important for increasing the country's self-sufficiency and, thus also, energy-related safety. Besides, the utilisation of renewable sources offers great environmental benefits; that is why it has been included in the priorities of the Energy Policy of the Slovak Republic.

According to (Production and consumption of electricity, 2022), the annual electricity consumption in Slovakia increased from 24.9 terawatt hours (TWh) in 2010 to 26.4 TWh in 2021. It is expected that in 2021–2030, the increase will be even higher due to the expected industry revival. Consumption of electricity is expected to reach 28.6 TWh by 2030. The key segments of the electricity market in Slovakia are thermal, hydroelectric, nuclear and

renewable energies. In 2019, the total production of electricity in Slovakia amounted to 27,808 GWh, while fossil fuels represented approximately 21% (Territorial just transition plans, 2022).

According to (Slovakia Power Market, 2022), nuclear energy, which currently represents more than 50% of the total production of electricity in Slovakia, will keep its dominant position in the country's energy mix in the next decade since Slovakia continues to be a net importer of electricity and thermal fuels. Nuclear energy is expected to represent 64.9% of the country's total production mix by 2035. Hydroelectric energy plays a key role in implementing the EU directive on renewable energy sources and contributes to achieving the EU objectives determined for the power sector for the years 2020–2030 (Guidance document, 2018). In Slovakia, hydroelectric energy is the second most important energy (preceded by nuclear energy) source of energy production in Slovakia. A share of hydroelectric energy in production is over 16% of the total amount. Although hydroelectric energy has great potential for the future, it is currently only used in almost 60%.

While only a few years ago, thermal energy was the third most intensively used energy type; today, it is pushed aside by renewable sources of electricity. As to thermal sources, a dominant technology of 2021 was gas, followed by coal and crude oil. Today, coal represents approximately 5% of the produced electric energy supplied to the market, and this decrease continues. By 2035, the cumulative capacity of thermal energy is expected to fall. As of February 2022, Slovakia operated 4 nuclear reactors, and 4 more are currently in preparation. The capacity of nuclear energy is expected to increase over the forecasted period. With regard to renewable energy, a dominant position was held by solar photovoltaics, followed by bioenergy and small hydroelectric power plants. Since Slovakia depends on the import of primary energy sources, the objective is to increase the share of renewable energy. To achieve this, the government introduced various stimuli that support the development of renewable sources (Slovakia Power Market, 2022). Solar sources of electric energy and the energy generated from biomass or biogas represent only small shares of total energy. These renewable energy sources are mostly used in households. Similarly, a share of hydroelectric energy is still small in Slovakia, although its potential is gradually being discovered, and it is planned to extend its existing capacities.

A strategic objective of the Energy Policy of Slovakia is to achieve a competitive low-carbon power sector that will be capable of providing safe, reliable and efficient supplies of all forms of energy at acceptable costs while considering consumer protection and sustainable development (Integrated National Energy, 2019). This objective is strongly affected by the EU objectives, while a strong emphasis is placed on the optimal utilisation of domestic energy sources and low-carbon technologies, such as RESs and nuclear energy. The basic pillars of the 2021–2030 Integrated National Energy and Climate Plan (2019) are energy safety, energy efficiency, competitiveness, sustainability and decarbonisation of the energy industry.

Evaluation methods

The evaluation of the development of energy consumption of electricity and fuels in Slovakia was based on data maintained by the database of environmental indicators (Envidat, 2022) and data obtained from the information portal of the Ministry of Environment of the Slovak Republic (Enviroportal, 2022).

The analysis and evaluation were carried out by applying basic statistical methods and time series analysis methods. A time series means a sequence of materially and spatially comparable observations chronologically arranged from the past to the present.

The moving average method is one of the basic tools of technical analysis, and it was developed because establishing trends from graphs may be rather complicated and inaccurate due to cyclical variations. A moving average partially eliminates such variations, and it is used in smoothing a trend. The development of energy consumption of electricity and fuels was forecasted by applying the method of exponential Smoothing (ETS). ETS is a forecasting method using the exponential smoothing algorithm to predict a future value based on existing (historical) values. This method is based on all previous observations, with the weights decreasing exponentially as the observations get older. Each model consists of three components: Error, Trend and Seasonal, whereas each component may be characterised as "Additive=A", "Multiplicative=M", or "None=N". With the Trend component, it is also possible to consider damping, particularly "Additive damped=Ad" or "Multiplicative damped=Md". There are several models with various suitable combinations of the types of all three components (Hyndman & Athanasopoulos, 2018). The ETS(M,A,N) model with multiplicative errors, an additive trend and no seasonality represents Holt's linear method with multiplicative errors; the ETS(A,A,N) model means the Holt's linear method with additive errors; the ETS(A,N,N) model means simple exponential smoothing with additive errors; and so on. In order to identify the best model, applying Akaike's Information Criterion (AIC) is advisable. The best model exhibits the lowest AIC value compared to the other models. Using the forecast package, a time-series forecasting model was created in the R language.

Result

The purpose of this study was to analyse the development of final energy consumption of electricity, fuels and heat in individual economy sectors (Agriculture, Transport, Industry, Trade and Services, and Households)

over the period of 2005–2020 and forecast energy consumption for the period of the next three years by applying the methods of time series analysis.

Total consumption of energy and fuels

Since 2010, the country has managed to reduce the final energy consumption of electricity and fuels gradually. In 2011, there was almost a 7% decrease compared to 2010. A change occurred in 2015 when the total energy consumption of fuels and energy increased by almost 5% compared to 2014, and such a rising trend continued till 2019. In 2020, the total energy consumption of fuels and energy was almost 8.3% lower than in 2019. Data indicate that total energy consumption of fuels and energy reached the level of 2005 while the resulting value was only 0.6% lower. Fig. 2 shows the development of total energy consumption of electricity and fuels in the years 2005–2020, together with the average annual consumption of 398,863 TJ (red line).

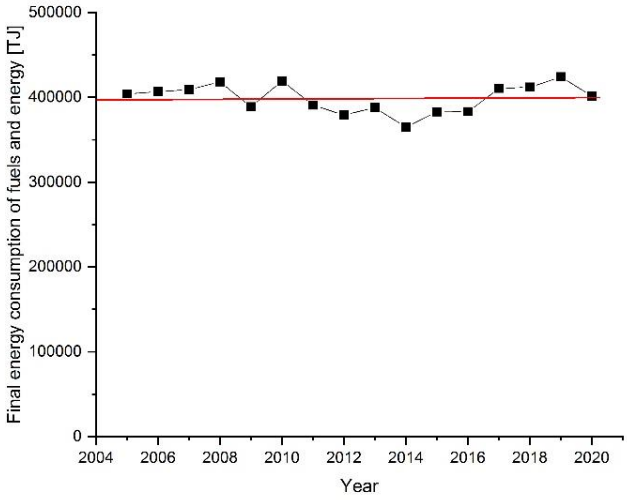

Fig. 2. Development of final energy consumption of fuels and energy

Fig. 3 and Fig. 4 show the development and shares of energy consumption for individual energy sources. Final energy consumption of gas fuels, heat and solid fuels significantly decreased over the analysed period. By contrast, the total consumption of RESs and electricity increased. An increasing trend was also achieved in the total energy consumption of liquid fuels (Fig. 3).

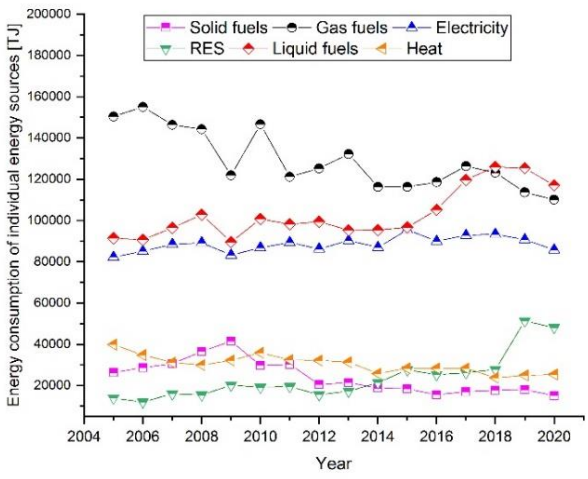

Fig. 3. Development of energy consumption

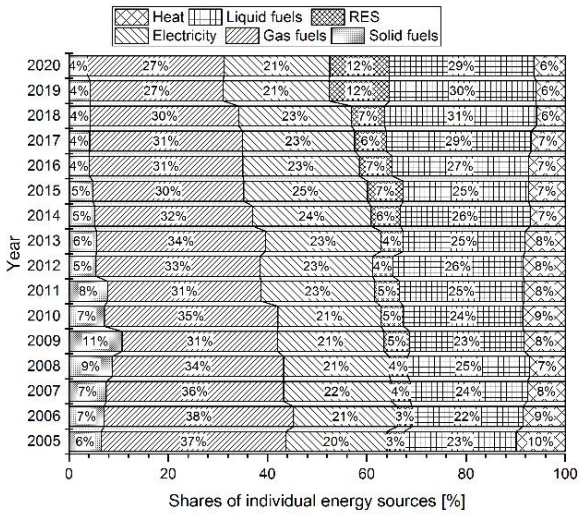

Fig. 4. Shares of individual energy sources of individual energy sources

A major share in the energy consumption of fuels and energies was represented by gas fuels (average annual share of 32.4%), followed by electricity (average annual share of 22.2%) and liquid fuels (average annual share of 25.8%). On the other hand, compared to 2005, a share of RESs in the total consumption increased; in particular, in 2020, a share of RESs was 3.5-fold higher than that in 2005 (Fig. 4). Gas fuels, liquid fuels and electricity had a larger share in the final energy consumption, amounting in total to almost 80% of energy consumption.

Development of energy consumption of electricity, fuels and heat in the analysed sectors is presented in Fig. 5. In the Transport sector; there was an increase of almost 39% in 2020 compared to 2005. A falling trend was observed for Industry and Trade and Services (Fig. 5). As for Households, in 2019, as much as almost a 29% increase was observed compared to 2018, while in 2020, the energy consumption of fuels and energies reached the highest value over the entire analysed period.

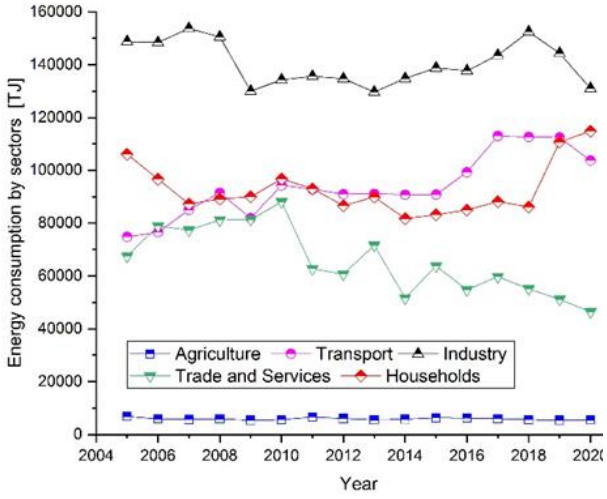

Fig. 5. Development of energy consumption by sectors

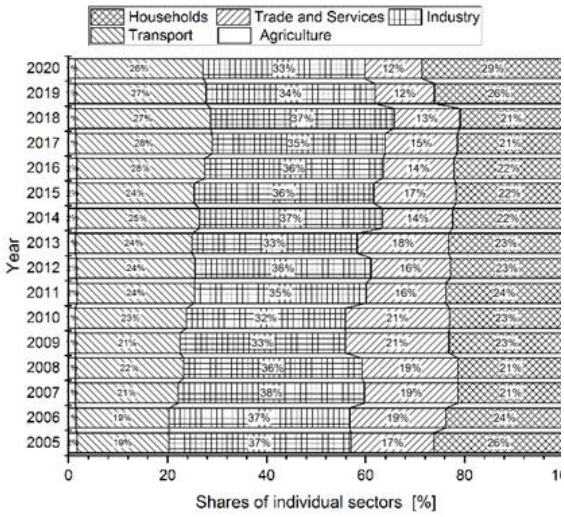

Fig. 6. Shares of individual sectors in energy consumption

Each year, Industry had the largest share in energy consumption across all sectors, with an average annual share of 35.2% (Fig. 6). A very similar share was observed in the Households (average annual share of 23.3%) and Transport (average annual share of 23.6%) sectors. In all the periods, Agriculture had only a negligible share in energy consumption of fuels and energy (average annual share of 1.5%)

Energy consumption of electricity, fuels and heat

Electricity

Over the analysed period of 2005–2020, the final energy consumption of electricity in Slovakia exhibited a growing trend with a 4.2% increase (an increase from 82,260 TJ in 2005 to 85,726 TJ in 2020). Fig. 7 and Fig. 8 show the development and the shares, respectively, of energy consumption of electricity by sectors.

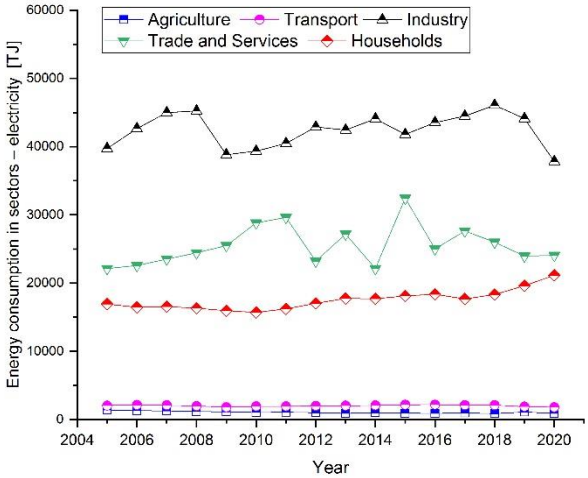

Fig. 7. Development of final energy consumption in sectors – electricity

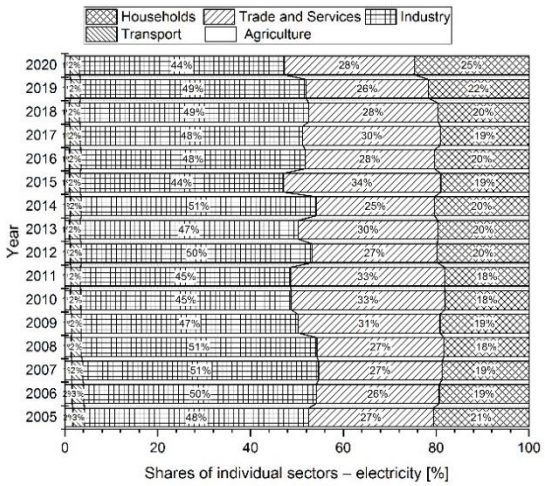

Fig. 8. Shares of individual sectors in final energy consumption – electricity

Each year, Industry had the largest share in the final energy consumption of electricity from among all the sectors. The largest share was observed in 2014 energy consumption in all sectors – electricity (53.6%) while the smallest one was observed in 2020 (45.9%). The average share of Industry was almost 47.9%, followed by Trade and Services (average share of 28.8%) and Households (average annual share of 19.8%). Transport (2.5%) and Agriculture (1.2%) held minimum average shares observed in the analysed period. In 2020, compared to 2005,

there was an increase in Trade and Services (by 8.7%) and Households (by 24.9%). In all the other sectors, the final consumption of electricity decreased.

Gas fuels

The final energy consumption of gas fuels over the period of 2005–2020 exhibited a decreasing trend. Compared to 2005, there was almost a 27% decrease. Fig. 9 and Fig. 10 show the development and the shares, respectively, of energy consumption of gas fuels by sectors. The highest consumption of gas fuels was observed for Industry (average annual share in the consumption was 40.8%). Households contributed to the final consumption of gas fuels with an average annual share of 37.9%, while Trade and Services represented 20.1%. Agriculture and Transport had only minimum shares in the final energy consumption of gas fuels (average annual shares of 0.9% and 0.3%). The most significant decrease was observed for Trade and Services (a 52.9% decrease in 2020, compared to 2005) and Agriculture (a 40.4% decrease).

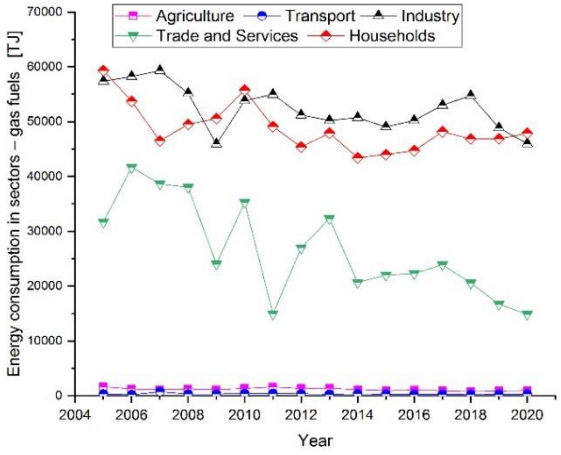

Fig. 9. Development of final energy consumption in all sectors – gas fuels

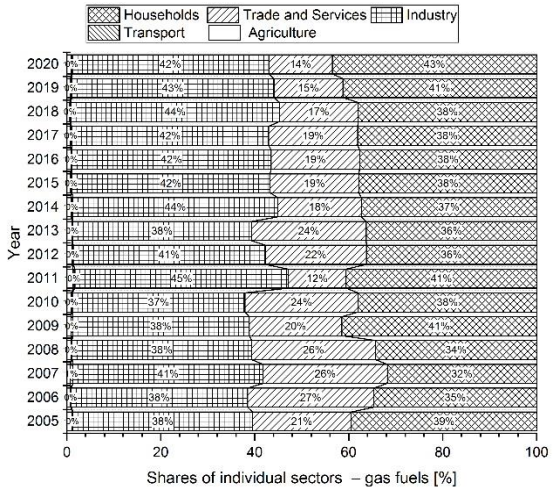

Fig. 10. Shares of individual sectors in final energy consumption – gas fuels

Liquid fuels

In 2005–2020, the final energy consumption of liquid fuels exhibited a rising trend (an increase of 28.1%); it increased from 91,387 TJ in 2005 to 117,111 TJ in 2020. Fig. 11 and Fig. 12 show the development and the shares, respectively, of energy consumption of liquid fuels by sector. Out of the analysed sectors, Transport had a dominant position in the final energy consumption of liquid fuels (average annual share of 88.6%). This means that the development of the final energy consumption of liquid fuels was affected by the final energy consumption of liquid fuels in the Transport sector. Agriculture and Industry's average annual shares were 9.2% (average annual shares of 2.8% and 7.4%), while the shares of the other sectors were at a minimal level. As for Trade and Services, the final energy consumption of liquid fuels significantly decreased, by as much as 93.1%, over the analysed period.

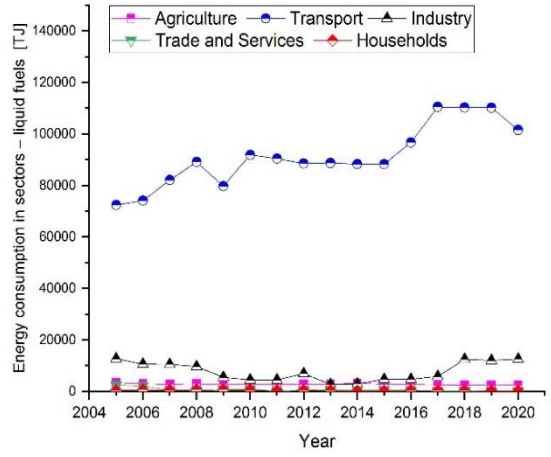

Fig. 11. Development of final energy consumption in sectors – liquid fuels

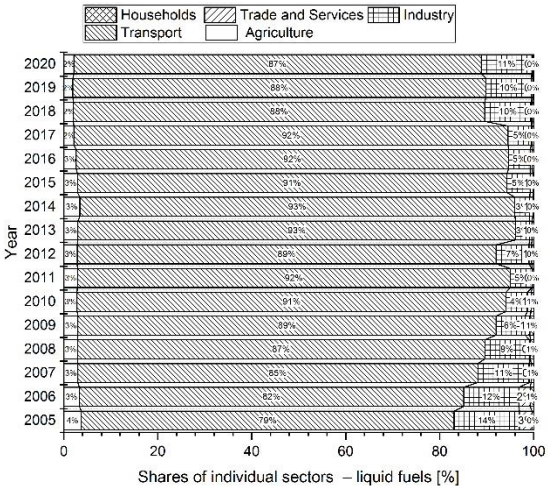

Fig. 12. Shares of individual sectors in final energy consumption – liquid fuels

Solid fuels

In the analysed period, solid fuels had the lowest share in the final energy consumption (average annual share of 6%). In the years 2005–2020, the final energy consumption of solid fuels exhibited a falling trend (a decrease of almost 42%); it decreased from 26,232 TJ in 2005 to 15,126 TJ in 2020. Fig. 13 and Fig. 14 show the development and the shares, respectively, of energy consumption of solid fuels by sector. The largest share in consumption was observed for Industry (average annual share of 68.4%), followed by Trade and Services (23.4%) and Households (8%). The share of the Agriculture sector was only minimal, representing 0.1%. As to the trends, Agriculture and Industry exhibited a significant decrease in final energy consumption of solid fuels (83% for Agriculture and 53% for Industry); however, consumption of solid fuels increased in the Trade and Services and Households sectors.

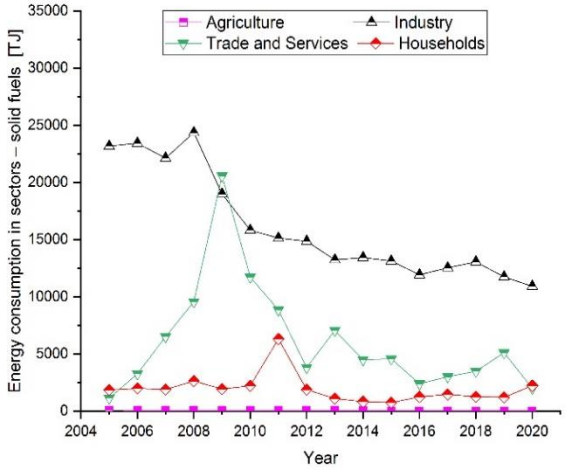

Fig. 13. Development of final energy consumption in sectors – solid fuels

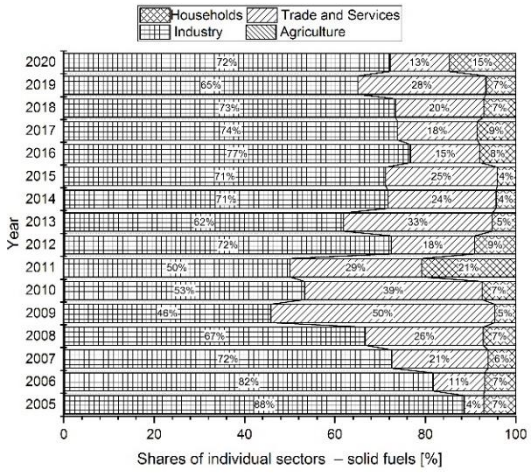

Fig. 14. Shares of individual sectors in final energy consumption – solid fuels

Renewable energy sources

In the analysed period, the final energy consumption of renewable sources and wastes had an increasing trend (an increase of almost 247%). Fig. 15 and Fig. 16 show the development and the shares, respectively, of energy consumption of renewable sources and wastes by sectors. The largest share in consumption was observed for Industry (average annual share of 80.6%), followed by Households (average annual share of 13.1%). In 2019, final energy consumption sharply increased in the household sector; in that year, final energy consumption in this sector was 14.7-fold higher than the one observed in 2018. In 2020, compared to 2019, a further increase was observed (by almost 7%). Shares of Agriculture and Trade and Services were minimal, with an average annual consumption of 2.5% and 3.6%, respectively (2.2% and 3.4%).

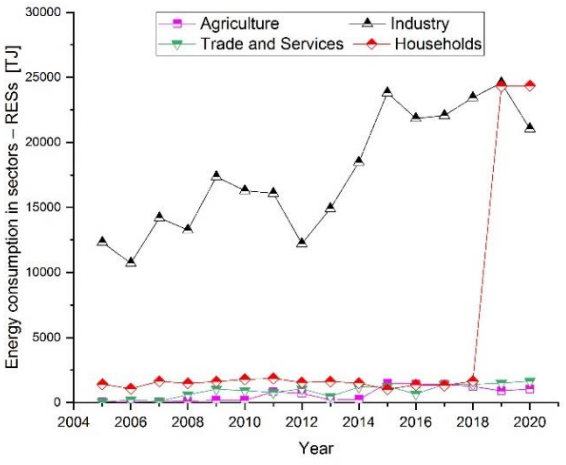

Fig. 15. Development of final energy consumption in sectors – RESs

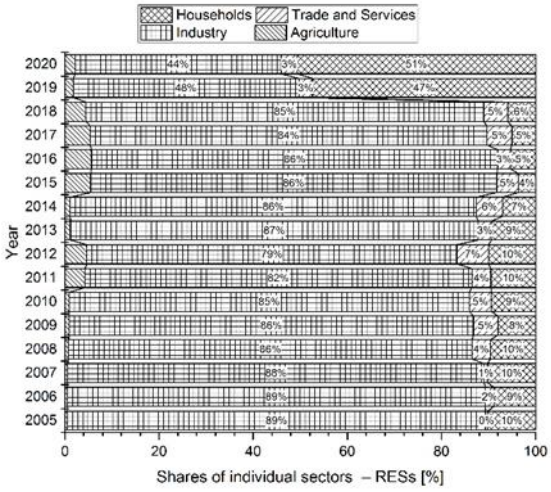

Fig. 16. Shares of individual sectors in final energy consumption – RESs

Heat

In the analysed period, the final energy consumption of heat exhibited a decreasing trend (a decrease of 36.4%). Fig. 17 and Fig. 18 show the development and the shares, respectively, of energy consumption of heat by sectors. The largest share in the consumption of heat was observed for Households (average annual share of 66.3%), followed by Trade and Services (average annual share of 19.3%) and Industry (average annual share of 14.1%). The smallest share in the final energy consumption of heat was observed for Agriculture, with an average annual share of 0.38%. In all of the sectors, the final energy consumption of heat decreased, while the most significant decrease occurred in Agriculture (by 69.2%).

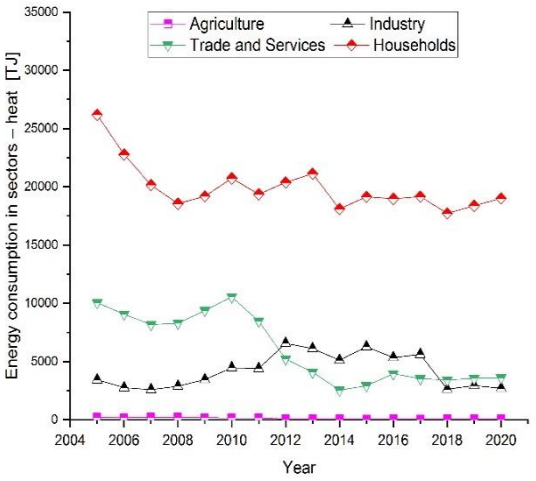

Fig. 17. Development of final energy consumption in sectors – heat

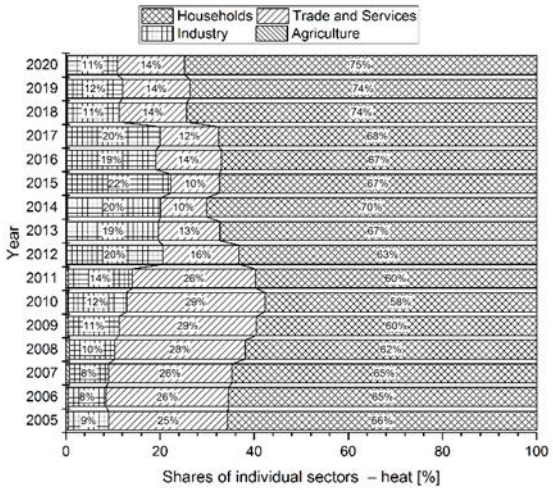

Fig. 18. Shares of individual sectors in final energy consumption – heat

Forecasted development of final energy consumption

The trend and the forecast of the development of the final consumption of fuels and energies were established using the smoothed data obtained by the simple moving average method. The data were smoothed out by applying the 5-point moving average.

In this part of our study, we examined a correlation between the final energy consumption of individual energy sources and time in the given analysed period. Based on Pearson's correlation coefficient *r*, it was concluded that there was a very strong positive correlation between the final energy consumption of RESs and time ($r = 0.90$) and between the final energy consumption of liquid fuels and the time ($r = 0.89$). Also, a very strong negative correlation was observed between the final energy consumption of solid fuels and time ($r = -0.93$), between the final energy consumption of gas fuels and time ($r = -0.96$), and between the final energy consumption of heat and time ($r = -0.97$). As for the final energy consumption of electricity, the correlation was strong ($r = 0.77$).

With regard to the individual sectors that were analysed for the below-listed energy sources, the resulting degrees of correlation between final energy consumption and time are summarised in Table 1.

Tab. 1 A summary table of the identified degrees of correlation

Sector	Energy source					
	Electricity	Gas fuels	Liquid fuels	Solid fuels	RESs	Heat
Agriculture	-0.830	-0.870	-0.830	-0.970	0.923	-0.903
Transport	0.085	-0.920	0.947	X	X	X
Industry	0.450	-0.818	0.420	-0.928	0.962	-0.072
Trade and Services	-0.004	-0.966	-0.817	-0.867	0.970	-0.919
Households	0.950	-0.760	-0.890	-0.687	0.733	-0.911

Note: no correlation ($|r|<0.29$); weak correlation ($0.30<|r|<0.49$); moderate correlation ($0.50<|r|<0.79$); and strong correlation (S, $0.80<|r|<1$); X – the source is not used in this sector

The values of Pearson's correlation coefficient *r* (Table 1) indicate that, for example, there is a strong negative correlation between the final energy consumption of electricity and time in all sectors, as confirmed by a falling trend.

A time-series model for the final energy consumption for 2005–2020 and a forecast for the upcoming period were established by applying the ETS method. Considering several models with various suitable combinations of all three components, we eventually chose the model with the lowest AIC level as the best. Forecasted development for the period of three years, together with a 95% prediction interval for final energy consumption, is presented in Table 2.

Tab. 2 Forecasted development of final energy consumption (energy source types)

Source [TJ]	2021		2022		2023	
	Point estimate	95% Prediction interval	Point estimate	95% Prediction interval	Point estimate	95% Prediction interval
Electricity	90,064	(86,526;93,602)	9,019	(86,228;94,158)	90,309	(85,958;94,659)
Gas fuel	111,294	(105,679;116,909)	109,627	(103,206;116,047)	108,009	(100,892;115,125)
Liquid fuel	123,295	(113,311;133,279)	124,870	(110,654;139,086)	126,414	(108,884;143,944)
Solid fuel	15,797	(12,985;18,610)	15,174	(11,625;19,082)	14,585	(9,789;19,291)
RESs	56,818	(50,187;63,449)	64,338	(51,373;77,304)	71,859	(50,272;93,445)
Heat	24,026	(23,006;25,046)	23,335	(219,212;24,758)	22,644	(20,927;24,362)

Fig. 19 and Fig. 20 show the smoothed time series of the development of final energy consumption of RESs and heat, respectively, together with the forecasted development. In addition to the point estimate (turquoise colour) of the forecast, the figures also present prediction intervals. The grey and the purple areas represent 95% and 80% prediction intervals, respectively, for the forecasts established using the resulting model ETS(M,A,N). Apparently, the best model for the final energy consumption of both RESs and heat was the ETS(M,A,N) model; this means that there was an additive trend (A) with multiplicative errors (M) and no seasonality (N). This model ETS(M,A,N) represents Holt's linear method with multiplicative errors.

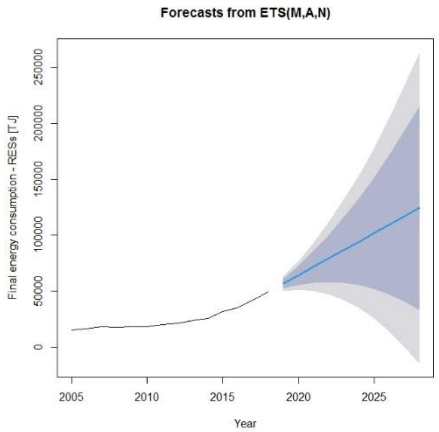

***Fig. 19. Development and a forecast of final energy consumption – RESs** t*

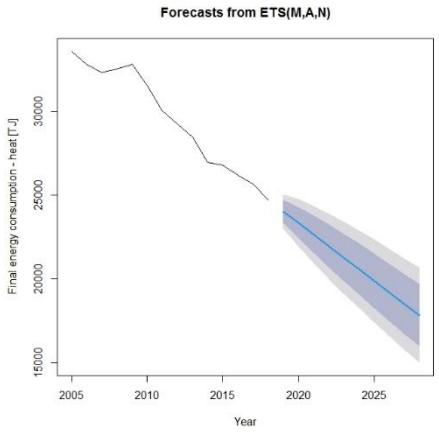

Fig. 20. Development and a forecast of final energy consumption – heat

The forecasted development of the final energy consumption of individual energy sources in the analysed sectors is presented in Tables 3–8.

Tab. 3 Forecasted development of final energy consumption of electricity (sector type)

Sector [TJ]	2021		2022		2023	
	Point estimate	95% prediction interval	Point estimate	95% prediction interval	Point estimate	95% prediction interval
Agriculture	1,006	(935;1,077)	1,017	(924;1,109)	1,027	(899;1,155)
Transport	1,740	(1,668;1,812)	1,622	(1,467;1,777)	1,504	(1,245;1,763)
Industry	42,678	(40,096;45,260)	42,678	(40,096;45,260)	42,678	(40,096;45,260)
Trade and Services	23,809	(21,837;25,781)	23,809	(21,837;25,781)	23,809	(21,837;25,781)
Households	1,740	(1,668;1,812)	1,622	(1,467;1,777)	1,504	(1,245;1,763)

Tab. 4 Forecasted development of final energy consumption of gas fuels (sector type)

Sector [TJ]	2021		2022		2023	
	Point estimate	95% prediction interval	Point estimate	95% prediction interval	Point estimate	95% prediction interval
Agriculture	912	(742;1,082)	891	(651;1,131)	871	(577;1,165)
Transport	257	(220;294)	247	(211;282)	237	(203;271)
Industry	49,062	(46,507;51,617)	48,744	(46,189;51,299)	48,435	(45,880;50,989)
Trade and Services	14,800	(12,863;16,737)	13,419	(11,662;15,175)	12,038	(10,462;13,614)
Households	46,973	(45,090;48,855)	46,776	(42,954;50,598)	46,619	(40,732;52,500)

Tab. 5 Forecasted development of final energy consumption of liquid fuels (sector type)

Sector [TJ]	2021		2022		2023	
	Point estimate	95% prediction interval	Point estimate	95% prediction interval	Point estimate	95% prediction interval
Agriculture	2,415	(2,263;2,567)	2,405	(2,153;2,657)	2,398	(2,026;2,769)
Transport	108,678	(100,147;117,209)	110,351	(99,503;121,199)	111,990	(99,185;124,794)
Industry	15,885	(13,963;17,806)	17,723	(14,448;20,999)	19,562	(14,409;24,715)
Trade and Services	238	(141;335)	213	(85;342)	190	(41;340)
Households	255	(189;322)	245	(153;337)	235	(124;346)

Tab. 6 Forecasted development of final energy consumption of solid fuels (sector type)

Sector [TJ]	2021		2022		2023	
	Point estimate	95% prediction interval	Point estimate	95% prediction interval	Point estimate	95% prediction interval
Agriculture	10.1	(6.86;13.35)	9.3	(4.84;13.71)	8.5	(3.26;13.78)
Industry	10,986	(9,682;12,289)	10,412	(81,118;12,707)	9,839	(6,244;13,435)
Trade and Services	3,347	(1,552;5,142)	3,229	(913;5,544)	3,121	(386;5,856)
Households	1,771	(742;2,799)	1,768	(283;3,253)	1,766	(185;3,624)

Tab. 7 Forecasted development of final energy consumption of RESs (sector type)

Sector [TJ]	2021		2022		2023	
	Point estimate	95% prediction interval	Point estimate	95% prediction interval	Point estimate	95% prediction interval
Agriculture	1,155	(680;1,630)	1,244	(348;1,839)	1,332	(623;2041)
Industry	23,401	(20,769;26,033)	24,057	(20,279;27,834)	24,698	(20,004;29,392)
Trade and Services	1,591	(1,395;1,787)	16,668	(1,472;1,864)	1,744	(1,549;1,940)
Households	24,406	(20,327;53,216)	244,067	(20,531;73,458)	244,068	(21,533;97,348)

Tab. 8 Forecasted development of final energy consumption of heat (sector type)

Sector [TJ]	2021		2022		2023	
	Point estimate	95% prediction interval	Point estimate	95% prediction interval	Point estimate	95% prediction interval
Agriculture	65.5	(50.2;80.6)	65.2	(36.1;94.4)	65.1	(20.52;109.7)
Industry	1,543	(895;2,191)	880	(569;2,329)	216	(55;2,641)
Trade and Services	3,637	(2,782;4,492)	3,696	(2,054;5,338)	3,744	(1,262;6,225)
Households	18,145	(17,327;18,963)	17,973	(17,161;18,785)	17,804	(16,996;18,612)

The development of final energy consumption was forecasted by applying the exponential smoothing method, which is based on historical observations, with the weights decreasing exponentially as the observations get older. It should be noted that the present times are not very favourable for the market with energies and primary energy sources and that it will significantly influence not only the development of energy consumption but also production as well as procurement of sufficient amounts of energy materials that are crucial for the smooth running of the economy.

Discussion and conclusions

The purpose of this research was to analyse the development of final energy consumption of individual fuel types, electricity and heat, including their shares in the final energy consumption in the given year, as well as the development of final energy consumption in selected sectors of the country's economy.

In 2005–2015, Slovakia managed to reduce the total energy consumption in individual sectors. Such a development was primarily achieved thanks to implementing multiple technologies with lower energy consumption in the industry and establishing energy-saving measures in households (e.g. external insulation of houses, using appliances with lower energy consumption etc.). On the other hand, the economic growth we have witnessed over the last four years was accompanied by an increase in energy consumption. The analysed data indicated that the last two years, 2019 and 2020, were also affected by the Covid-19 pandemic.

Slovakia has already established a low-carbon mix of electricity sources, and the share of carbon-free electricity production achieved almost 80% in 2020. In that year, nuclear power plants had the largest share in the production of electricity (53.2%). They were followed by thermal power plants (21.5%), hydroelectric power plants (16.8%), power plants using RESs (8.0%) and other power plants (0.4%). In the long term, Slovakia exhibits a gradual decrease in electricity production in thermal power plants while the importance of nuclear energy and energy obtained from RESs increases.

Accurate forecasting of energy consumption plays a very important role in these challenging times with regard to supplying the country with the energy materials that are crucial for its economy. It seems that the development of final energy consumption of electricity, RESs and liquid fuels has an increasing trend. On the other hand, the development of solid fuels, gas fuels and heat exhibits a decreasing trend.

According to the research results, we may conclude the following:

- In all of the analysed sectors, the development of final energy consumption of gas fuels, solid fuels and heat exhibited a falling trend;
- Development of final energy consumption of electricity had an increasing trend in the Industry and Households sectors but a decreasing trend in Agriculture;
- Development of final energy consumption of liquid fuels exhibited a growing trend in Industry and Transport, whereas the trends in the other sectors were of a decreasing nature;
- In all of the analysed sectors, the development of final energy consumption of RESs and wastes had an increasing trend.

In the present times of an ongoing energy crisis, it becomes increasingly urgent to put emphasis on regulated energy demand, implementation of energy-saving measures, the highest rate of energy efficiency, and a search for alternative and renewable energy sources. Implementation of energy-saving measures and solutions requires not only systematic collaboration of multiple organisations, institutions and individuals but also awareness of the basic information on energy consumption and utilisation. This may eventually be reflected in increased quality of life of people, improved housing and working conditions, as well as increased competitiveness of the industry and improved conditions for business. Another factor that is very important for reducing energy consumption is the awareness and education of the population. All these measures are only a fraction of all that needs to be done to facilitate the mitigation of negative environmental effects of the consumption of electric energy and other energies from the global point of view.

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