

# ANALYSIS OF ENERGY CONSUMPTION OF THE VISEGRAD COUNTRIES

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The utilization of renewable energy sources has an increasing role in the EU's climate and energy policy. There are several reasons for increasing the use of renewable energy. The motives are the reduction of imported dependence on fossil fuels, mitigation of the adverse environmental impact of the energy sector and boosting of industrial development. The study provides a comprehensive overview on the structure and utilization of energy production of the Visegrad countries, focusing on the dependence on energy imports. The purpose of the article is to analyze the gross inland energy consumption of the Visegrad countries and to examine the relationship between renewables and non-renewable energy sources. In the course of the analysis, we tried to find out which non-renewable energy carrier is replaced by the renewables.

**Keywords:** correlation matrix; gross inland energy consumption; renewable energy; Visegrad countries

## 1 Introduction

In the recent decades, the economic growth was significant in the world due to the low cost of using natural resources for production and transportation. Today, only a few regions are producing fossil energy in the world, in most of them the political situation is unstable, therefore these regions are fairly uncertain source of energy (Harangi-Rakos et al., 2017). With the rise of population of the Earth, the energy consumption is also significantly growing, mainly in the backward Asian and African regions. In addition to the growing production and the change in lifestyles – especially in developed countries – also the energy demand increases (Fodor, 2012). The improvement of energy efficiency reduces the growing demand for energy, however the renewable energy has become a key issue to partially replace the fossil energy. The role of renewable energy is outstanding even if the renewables are often available in smaller quantities, the production can not be regulated and some of them depend on the weather conditions.

### Energy situation of the European Union

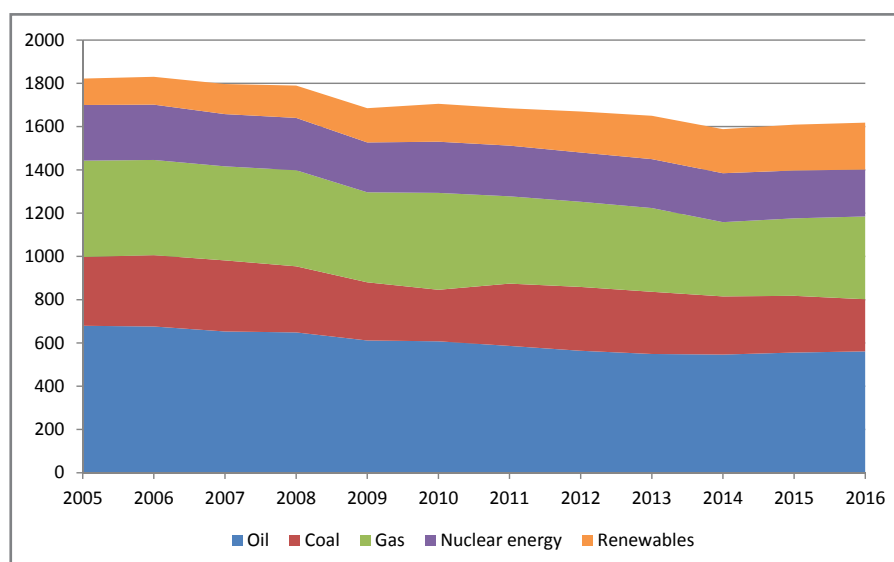
The primary energy production of the European Union amounted to 755 Mtoe in 2016, it means a 15% drop compared to the year 2006. The composition of primary energy production varies widely among the countries. In the EU, the coal accounted for 19%, the oil for 10%, the natural gas for 14%, the renewables for 28% and the nuclear energy for 29% of the primary energy production in 2016. The oil and gas production as well as the refining capacity of the EU have decreased more rapidly than energy demand in the last period, which has had negative consequences for energy security (Honvari, 2015). As a result of the decline in domestic production, the EU had to rely increasingly on primary energy imports to meet the demand. The EU consumed 1483 Mtoe import energy in 2016, meanwhile it exported 579 Mtoe of energy. The EU is the world's largest energy importer, 53% of all energy was imported, amounting to 350 billion euros in 2016. There

are several EU member states which depend on some suppliers to a great extent, which makes them vulnerable. Russia has been the largest importer of crude oil and natural gas for the EU as well as the main supplier of solid fuel. Import dependency is also demonstrated by the fact that the total gas import of six member states depend on one external supplier. The transport sector relies on 94% of petroleum products and 90% of them come from import. The most significant energy consumers are Germany (19.3%), France (15.1%), United Kingdom (11.5%), Italy (9.4%) and Spain (7.5%).

The gross inland consumption of the European Union decreased by 10% from 1,822 Mtoe to 1618 Mtoe between 2006 and 2016. Meanwhile the final energy consumption decreased from 1193 Mtoe to 1107 Mtoe, that is a 7.2% decrease. The fossil fuels are dominant in the European Union's gross energy consumption, the fossils account for 73.2% of energy consumption. The oil represented 34.7% (561 Mtoe), the natural gas 23.7% (383 Mtoe), and the coal products 14.9% (241 Mtoe) in consumption in 2016. The importance of non-fossil fuels is much smaller in the European Union. The nuclear energy accounted for 13.4% (217 Mtoe) in total energy consumption (Figure 1).

The EU's renewable energy consumption reached 217 Mtoe in 2016. The biomass has the largest share with 45%, followed by hydropower (14%), wind power (12%), biogas (8%), biodiesel (5%), municipal waste (5%), solar PV (4%), geothermal energy (3%), solar energy (2%). In the EU, the renewables represent 29.6% of electricity, 7.1% of transport and 19.1% of heating and cooling.

Between 2006 and 2016, an opposite tendency can be observed in energy consumption of the EU. The consumption of fossils decreased by 17.8% and nuclear energy by 15.8%, however the consumption of renewable energies increased by 78%. Renewable energy is the only type of the energies whose volume and share have been steadily increasing in total energy consumption.



**Figure 1** The Development of European Union's gross inland consumption (Mtoe)  
Source: own edit based on British Petrol statistical review of world energy (2018)

energy system. The EU countries agreed on a new renewable energy target of at least 27% of EU's final energy consumption, a 40% cut in greenhouse gas emissions compared to 1990 levels, a target for an improvement in energy efficiency at EU level of at least 27% by 2030.

In comparison with the traditional energy production, the renewable energy production is not yet competitive under current market conditions, due to the high investment costs of technologies and to environmental effects of externalities not being adequately reflected in market prices. Therefore, support is needed for renewable energy production (Fodor, 2012). The EU policy on energy aims to ensure security of energy supply in the member states, to promote energy efficiency and energy saving, as well as to increase the share of renewable energy. Solidarity among the member states is fundamental, however each country is responsible for his own energy security. The spread of renewables may be impeded by the availability of fossil resources within a country (eg. UK, Poland). The factors that provide the framework for countries as follows different international obligations, differences in planning/licensing cultures, public awareness concerning renewables, technical differences (Reiche and Bechberger, 2004).

## Material and methods

In the article, we analyze the gross inland energy consumption of the four Visegrad countries. The gross inland energy consumption represents the quantity of energy necessary to satisfy inland consumption of the geographical entity. In narrow sense, it represents the sum of primary energy production and net import (import-export). In broad sense, it is supplemented with recovered products, variations of stocks, bunkers and direct use. The diagram of energy flow can be illustrated by the Sankey diagram (Figure 2), where the direction of flow is shown by the arrows and the width of the arrows is shown proportionally to the flow quantity.

The Figure 2 is "simplified" because it does not indicate the network loss, the energy

## The role of renewables in the European Union's energy policy

The hydropower, wind, solar, biomass energy are even more expensive than fossil-based power generation. However, due to steadily declining stocks of fossiles and rising energy prices, it is increasingly worthwhile to switch to renewable energy sources (Popp, 2013). The utilization of renewable energy sources has an increasing role in the EU's climate and energy policy. By using more renewables to meet its energy needs, the European Union lowers its dependence on imported fossil fuels and makes its energy production more sustainable. Influenced by economic and environmental interests the European Union committed itself to increase the utilization of renewable energy sources at the end of 1990s. The Energy Policy White Paper issued by the European Commission initiated a common Renewable Energy Strategy and set up an Action Plan in 1997. The indicative objective was 12% share for the contribution by renewable sources of energy to the European Union's gross inland energy consumption by 2010. Recognizing the growing dependence on imports, the European Commission defined the

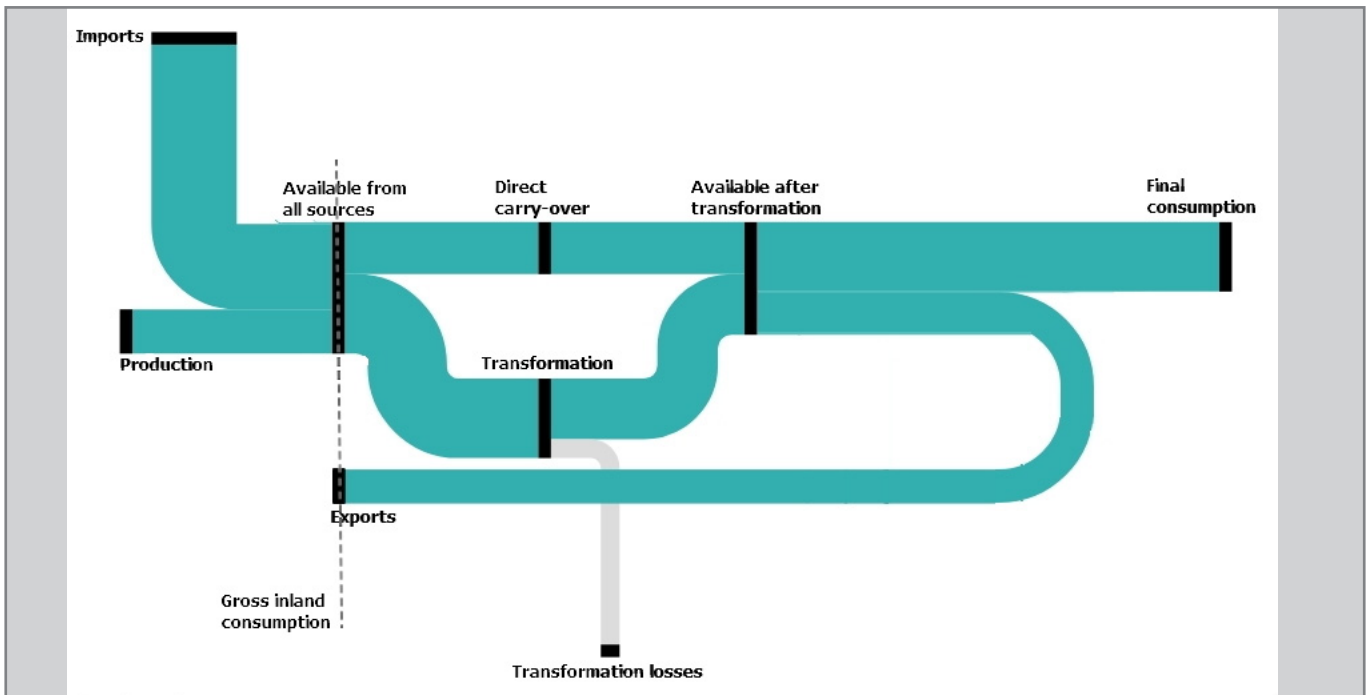
objectives of energy policy in the Green Paper in 2006. Three key energy policy objectives were identified, improved competitiveness, security of supply, and protection of the environment. The Directive 2009/28/EC established an overall policy for the production and promotion of energy from renewable sources in the EU. The directive set a binding target of 20% final energy consumption from renewable sources by 2020 – to be achieved through the attainment of individual national targets. Each EU country must have showed what actions they would intend to take to meet their renewables targets (including sectorial targets for electricity, heating and cooling, and transport). The countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020. The table 1 shows the development of renewable energy share in the final energy consumption and the national targets 2020. It should be noted that the gross inland energy consumption should not be confused with the final consumption.

The European Council set even more ambitious goals by increasing commitments by 2030. The aim was to promote the EU achieve a more competitive, secure and sustainable

**Table 1** The development of renewable energy share in the final energy consumption and the national targets 2020

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2020 target
EU-28	11.10%	12.40%	12.90%	13.20%	14.40%	15.20%	16.10%	16.70%	17.00%	20.00%
Poland	7.70%	8.70%	9.30%	10.30%	10.90%	11.40%	11.50%	11.70%	11.30%	15.00%
Czech Republic	8.60%	9.90%	10.50%	10.90%	12.80%	<b>13.80%</b>	<b>15.00%</b>	<b>15.00%</b>	<b>14.90%</b>	13.00%
Slovakia	7.70%	9.40%	9.10%	10.30%	10.40%	10.10%	11.70%	12.90%	12.00%	14.00%
Hungary	8.60%	11.70%	12.70%	<b>14.00%</b>	<b>15.50%</b>	<b>16.20%</b>	<b>14.60%</b>	<b>14.40%</b>	<b>14.20%</b>	13.00%

Source: Eurostat database (2018)



**Figure 2** Simplified Sankey Diagram for energy flow  
Source: own construction based on Eurostat (2018)

consumption of the system (transformation, transport, etc.), only the transformation loss. However, the results are not affected by these factors. The data of analysis come from the database of the European Commission Eurostat and the International Renewable Energy Agency (IRENA) regarding the period between 2010 and 2016.

In the study, we used comparative time series analysis. The purpose of the article was to analyze the gross inland energy consumption

of the Visegrad countries and to examine the relationship between renewable energy and non-renewable energy sources. In the course of the analysis, we tried to determine which non-renewable energy carrier was replaced by the renewables in the Visegrad countries. The replacement of energy sources with each other was analyzed by correlation matrix and it was evaluated at 5% significance level. Then, we applied partial correlation analysis under control variables to decide whether the

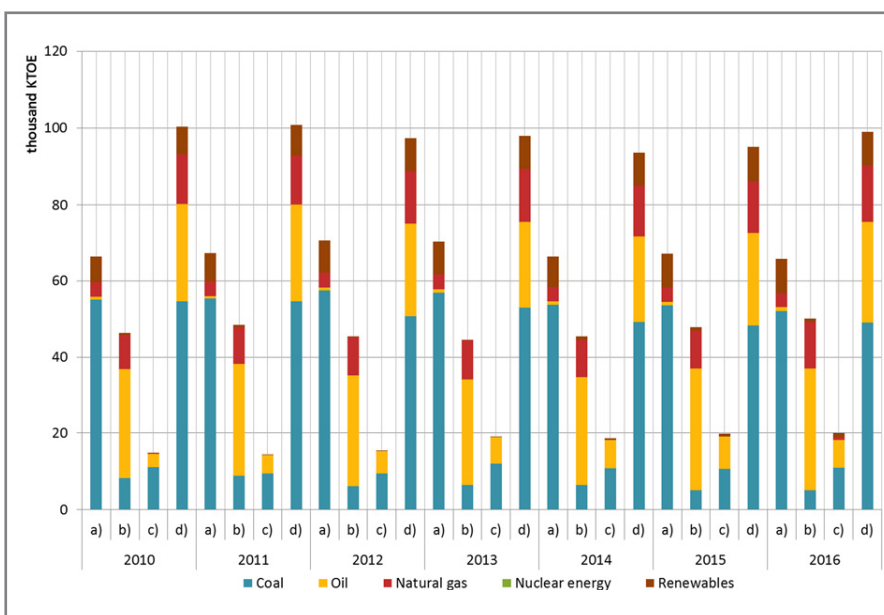
relationship calculated in the correlation matrix exists or not. The evaluation happened by using IBM SPSS Statistics 20, GRET 2018a, and MS-Office Excell 2016.

## Results and discussions

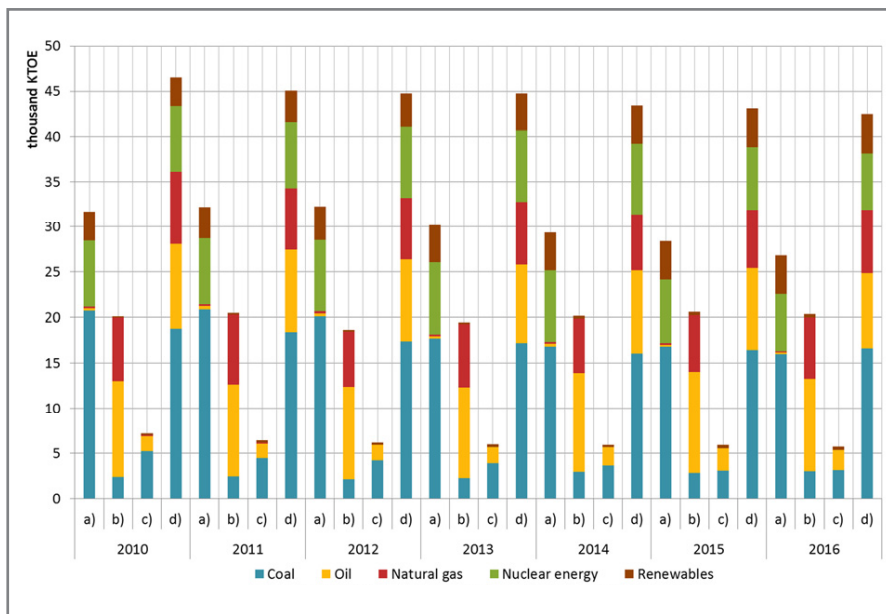
### Poland's energy consumption

Poland's annual primary energy production was 66 thousand ktoe in the period 2010–2016. Energy production of the country is mainly based on black and brown coal. The coal accounted for 80% of total primary production. Poland is Europe's largest coal producer with 75 million tonnes per year. Poland's import energy consumption was 50.1 thousand ktoe in 2016. The country's energy import is based on oil with 64% share. The gas has a share 24% and the coal has a share 10% in energy import. In international comparison, Poland's import energy dependency is low (30%), Russia is Poland's largest supplier. Poland's energy exports amounted to 20 thousand ktoe in 2016. In exports, like in domestic consumption the coal is dominant with a share 50%. The country's gross energy consumption decreased by 1.4% between 2010 and 2016 and amounted 99 thousand ktoe in 2016. The coal was dominant in the gross inland energy consumption with a share of 49%, the 27% came from oil, 15% from natural gas and 9% from renewable energy (Figure 3).

Poland's gross renewable energy supply was 8769 ktoe in 2016. The biomass accounted for 75% and wind energy for 12% of the total.



**Figure 3** Development of Poland's energy consumption (thousand ktoe)  
Source: own edit based on Eurostat database (2018)  
a – primary production, b – import, c – export, d – gross inland consumption



**Figure 4** Development of Czech Republic's energy consumption (thousand ktoe)

Source: own edit based on Eurostat database (2018)

a – primary production, b – import, c – export, d – gross inland consumption

In Poland, 13.3% of electricity, 3.9% of transport and 14.7% of cooling and heating generated from renewable sources.

### Energy consumption of Czech Republic

The primary energy consumption of the Czech Republic amounted 26.8 thousand ktoe in 2016, it means a 15% decrease compared to the value of year 2010. The energy production is mainly based on coal. The coal accounted for 60%, the nuclear energy for 23% and the renewables for 16% of total primary production. Import energy consumption of Czech Republic was 20.3 ktoe

in 2016. The oil has a half, the gas has one third and the coal has a share 15% in the country's energy import. The Czech Republic imports the coal from Poland, the oil and natural gas primarily come from Russia. The energy dependency of the country (32%) is significantly lower than average level of the European Union. The Czech energy export amounted to 5.8 thousand ktoe in 2016, in which the coal has a share 55% and the crude oil has a share 38%. The Czech Republic's gross energy consumption decreased by 8% between 2010 and 2016, and reached the 42.4 thousand ktoe in 2016. The coal represents 40% in the gross

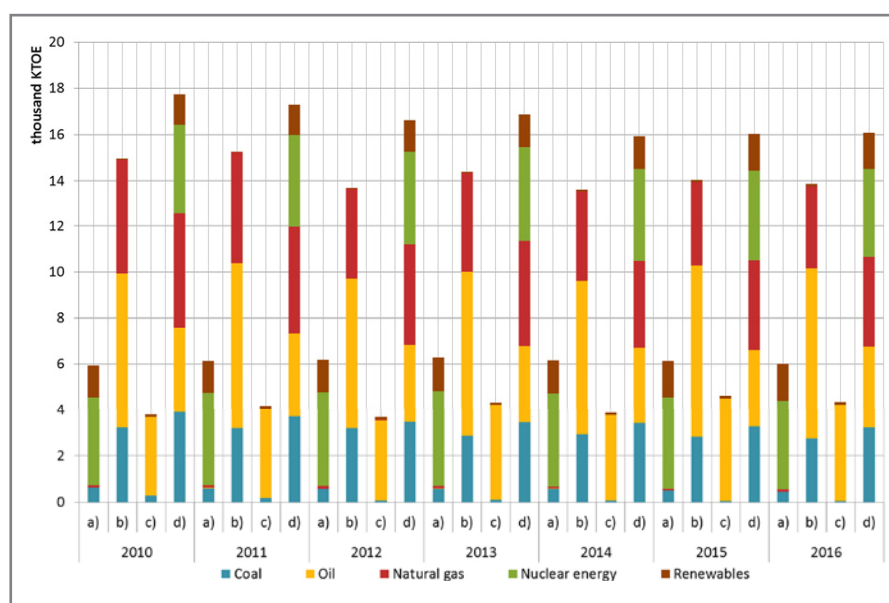
energy consumption, the oil is the second with share 19%, the gas has a share 17%, the nuclear energy has a share 14% and the renewable energy has a share 10% in the gross energy consumption (Figure 4).

The gross renewable energy supply of the Czech Republic increased by 38% during the examined period and amounted to 4,310 ktoe in 2016. The biomass accounted for 67% and the biogas for 14% of the total. In the Czech Republic, the renewables represent 13.6% of electricity, 6.4% of transport and 19.8% of cooling and heating.

### Slovakia's energy consumption

Between 2010 and 2016 the primary energy production of Slovakia increased by 3.8% and reached 6 thousand ktoe in 2016. Slovakia's energy production is mainly based on nuclear power. Nuclear energy represents 64% of the energy production and the renewables has a share 27% of the total. Slovakia's import energy consumption amounted to 13.8 ktoe in 2016. The country's energy import is based on oil with 53% share. The gas has a share 26% and the coal has a share 20% in energy import. Import energy of Slovakia came primarily from Russia (oil, natural gas) and from Czech Republic (coal). The country's import energy dependency (59%) is higher than the average level of the European Union. Slovakia's energy export was 4.3 thousand ktoe in 2016, 96% of which was oil (mainly transit). Gross energy consumption of Slovakia fell from 17.7 ktoe to 16.1 ktoe between 2010 and 2016. Slovakia's gross energy consumption is balanced. The natural gas and nuclear energy were dominant in the gross inland energy consumption with a share of 24–24%, 22% came from oil, 20% from coal and 10% from renewable energy in 2016 (Figure 5).

The gross renewable energy supply of Slovakia was 1,577 ktoe in 2016, of which the biomass amounted to 52%. The hydropower accounted for 24%, the biogas for 10% and the biodiesel for 8% in the total. In Slovakia, 22.5% of electricity, 7.5% of transport and 9.9% of cooling and heating generated from renewable sources.



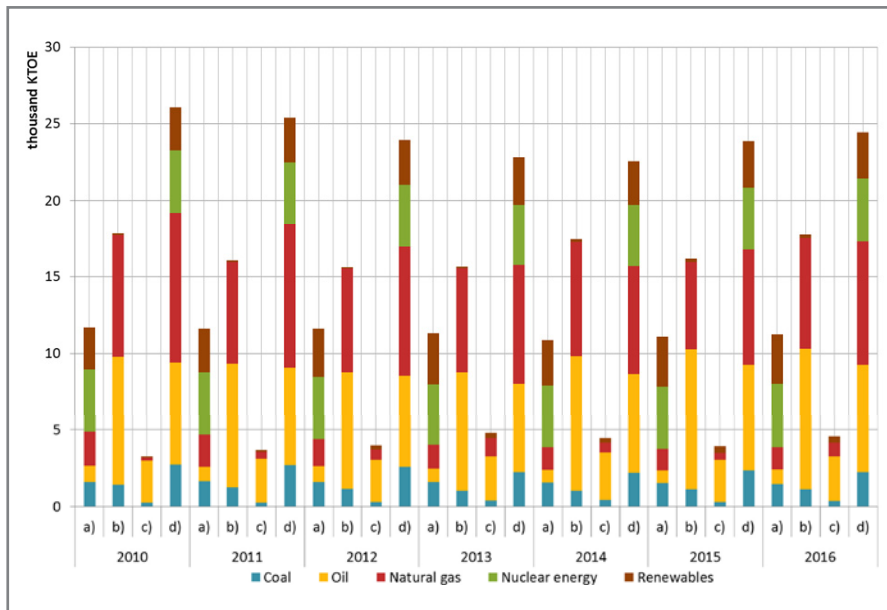
**Figure 5** Development of Slovakia's energy consumption (thousand ktoe)

Source: own edit based on Eurostat database (2018)

a – primary production, b – import, c – export, d – gross inland consumption

### Hungary's energy consumption

The primary energy consumption of Hungary amounted to 11.2 thousand ktoe in 2016, it means a slight decrease (3.8%) compared to the value of year 2010. In the primary energy production the nuclear energy represents 37%. The renewables holds the second place, contributing 28% of energy production. The coal and natural gas have



**Figure 6** Development of Hungary's energy consumption (thousand ktOE)

Source: own edit based on Eurostat database (2018)

a – primary production, b – import, c – export, d – gross inland consumption

a share 13%, the share of oil was 9% in 2016. Hungary consumed 17.8 thousand ktOE import energy, that is much more than the domestic production. The energy import showed a hectic movement during the seven years. The oil and the natural gas are dominant in the energy imports of Hungary, with a share of 51% and 40%. Hungary's import energy dependency is average (55%) in comparison to the European Union level. The Hungarian energy exports was 4.6 ktOE and the share of oil reached 58% in 2016. The gross energy consumption of Hungary amounted to 24.5 thousand ktOE, which is by 5.7% less than value of year 2010. The 33% came from gas, 29% from oil, 17% from nuclear energy, 12% from renewables and 9% from coal in gross energy consumption (Figure 6).

Hungary's gross renewable energy supply was 3,000 ktOE in 2016, of which the biomass amounted to 80%. The biodiesel and geothermal energy represented 4%, the biogas accounted for 3%, the municipal waste for 3%, the biogas oil for 2% and the wind energy for 2%. In Hungary, the

renewables represent 7.2% of electricity, 7.4% of transport and 20.9% of cooling and heating.

### Evaluation of relationship between non-renewable energy and renewables

For the European Union as a whole, the examination of relationship between renewables and non-renewable energy sources showed the following results. The values of the correlation matrix (Table 2) show that the growth of renewable energy was due to the decrease of nuclear energy (-0.9635), of coal (-0.7692) and of oil (-0.7733). (Natural gas proved to be out of the 95% confidence interval.) The partial correlation calculation based on control variables showed that the relation between renewables and coal, as well as renewables and oil can not be detected. However, the relation between renewables and nuclear energy can be detected. It can be stated that in the European Union the renewables have replaced mainly the nuclear energy.

In the case of Poland, the renewable energy was in negative correlation with the coal (-0.8547) and in positive correlation with the gas (+0.7826). (The oil proved to be out of the 95% confidence interval, that is why it is not relevant.) Nuclear energy is not consumed in Poland. The partial correlation calculation showed that the negative correlation decreased between the renewables and the coal in case, when the natural gas was the control variable. Therefore, the natural gas consumption affects the renewable-coal relation. However, to what extent the renewables replace the coal can not be detected. Based on the analysis, it can be concluded that the natural gas and renewables together replace the coal in Poland.

In the case of Czech Republic, the situation is clear regarding the relation between renewables and non-renewable energy sources. Only the renewables-coal relation was relevant. (The other three non-renewable energies proved to be out of the 95% confidence interval.) It was confirmed by the partial correlation test, in case, when the oil, the natural gas and the nuclear energy were the control variables. In the Czech Republic the renewables replaced the coal.

In the case of Slovakia, the renewables were in negative correlation with the coal (-0.8659) and with the natural gas (-0.7719), which was proved only for the coal by partial correlation calculation (but only partially). In Slovakia, the renewables replaced mainly the coal during the examined period.

Hungary is the only country among the four, where the renewables did not show significant correlation with any non-renewable resource. The highest correlation value (-0.5800) was for coal, however the replacement of renewables for coal was not proved. In the case of Hungary, it can not be detected any non-renewable energy that were replaced by the renewables.

Concerning the results, it should be noted that the non-renewable energy sources were clearly separated, but the renewables were examined as a whole. Regarding the composition, the renewables can be very different by countries.

**Table 2** Correlation matrix of replacement of non-renewable energies for renewables

Energy carrier	Poland	Czech Republic	Slovakia	Hungary	EU-28
Coal	-0.8547	-0.9467	-0.8659	-0.5800	-0.7692
Oil	-0.3778	-0.6256	-0.3999	-0.2838	-0.7733
Natural gas	0.7826	-0.7115	-0.7719	-0.5163	-0.7442
Nuclear energy	-	-0.2352	-0.2670	-0.2221	-0.9635

Source: own calculation on Eurostat database (2018)

The biomass is the dominant renewable energy in each country, however some member states have other renewable sources with higher rate than the average of the EU (eg. the wind in Poland, the biogas in the Czech Republic, or the hydropower in Slovakia).

## Conclusions

The structure of energy production of the Visegrad countries is different due to the differences of natural endowments. However, the results showed that the renewables replaced mainly the coal. The four countries are highly dependent on oil and natural gas. The main goal is to reduce the consumption of fossil energy and to replace them by renewables in the future. Reduction of oil consumption could be achieved by increasing consumption of biofuels and by using more electric or hybrid power devices. Natural gas used for heating can be replaced by biomass, solar, geothermal energy. The coal, which is mainly responsible for environmental damage can be replaced by biomass, in case of electric power generation the coal can be replaced by hydropower, wind or solar energy. In addition to the increasing the share of renewable energy, the EU also put an emphasis on improvement of energy efficiency (savings). During the examined period, the decreasing of energy consumption was affected not only by the negative impact of the 2008 crisis, but also the spread of efficient consumers (eg: more energy-efficient motors, passive houses, modernization of light technics etc.)

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