ANALYSING SUSTAINABLE ENERGY CONSUMPTION IN EUROPE

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ABSTRACT
Sustainability depends primarily on the available resources. At present our world uses much more resources than it would be allowed by sustainability. Due to this the current economic system can be operated only with substantial extra sources. If these sources run out, the economy can be at serious risk. All these lead to the conclusion that sustainable energy management is an important part of sustainable development. One of the areas of sustainable energy management is the exploitation of renewable energy sources. Sustainable energy management should, however, include the management of permanently diminishing fossile energy sources, too, because the complete replacement of fossile sources with renewable ones – by the present technological means - is not possible within foreseeable future. The study applies Principal Component Analysis to examine the energy consumption of European countries in 2011. Those European countries where the volume of energy consumption is higher put more emphasis on the use of renewable energy sources. It can be concluded that Western Europe is better at implementing sustainable energy consumption. In addition to the use of renewable energy sources, the rationalizaton of energy consumption, changing consumer habits and attitudes can help to implement sustainable energy management.

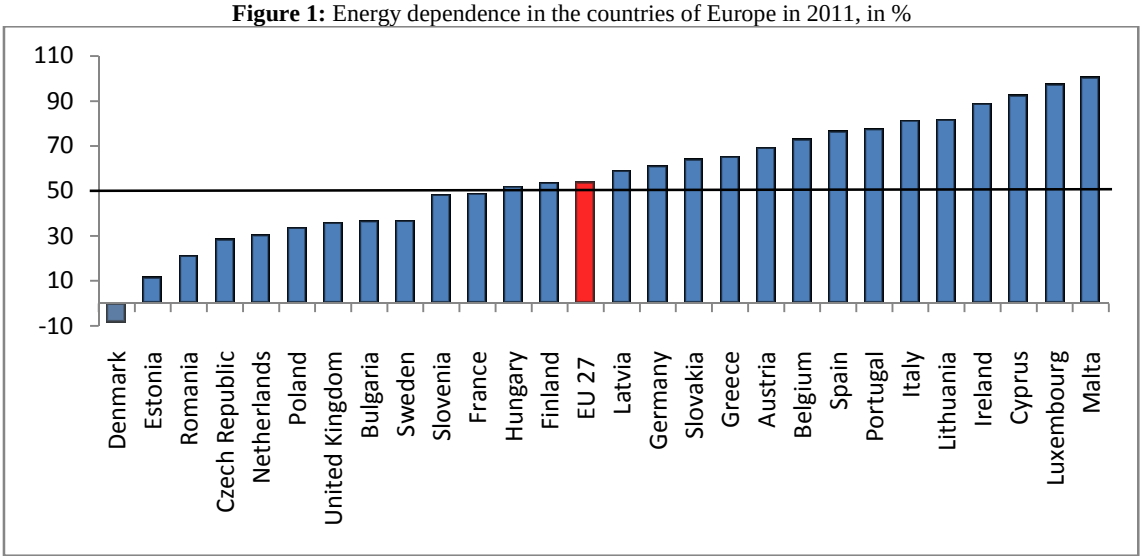
KEY WORDS: sustainable energy management, renewable energy sources, fossile energy sources, Principal Component Analysis

INTRODUCTION

In regard to the concept and essence of sustainable development a number of papers have been published. According to Herman Daly, the sustainable development means achieving permanent social welfare without expanding beyond ecological carrying capacity.
The resources of Earth are exhausting day by day, but the energy needs of world is permanently increasing. At present the demands of humankind placed on natural resources exceed the biocapacity of Earth already by 25%.
The primary energy use of the world has grown by almost 70% since 1980. The volumes of exploitable fossil energy sources, however, are permanently reducing. More than 80% of the global primary energy need is met by fossil energy sources, next to them the share of renewable energy sources seems to be insignificant. The expansion of use is going on in the future therefore – according to some reliable forecasts – the high proportion of fossil energy sources cannot be maintained safely in the long run. Out of fossil energy sources produced in the world the crude oil is the first where man will probably soon reaches or have already reached the highest quantity brought up to the surface. In practice it means that half of the totally available oil quantity have already been produced [National Energy Srategy 2030, 2011].
Energy links economic development, social development and environment which enables the world to develop. Development is impossible without energy and sustainable development is impossible without sustainable energy management. In order to ensure sustainable energy for everybody by 2030, three targets should be definitely approached. These are as follows: ensuring global access to services of modern energetics, doubling renewable energy within the energy mix and doubling energy efficiency [Sustainable energy for all, 2012].
The dependence of the European Union on imported energy sources, especially oil and - just recently - natural gas, is behind the political concerns regarding the safety of energy supply.

The safety of primary energy supply of the European Union can be endangered if the massive import is concentrated in the hands of relatively few partners [EUROSTAT, 2012].
The Eurostat calculates the rate of energy import dependence by dividing net energy import by gross consumption. The energy dependence demonstrates how the given country relies on energy import in order to meet its demand for energy.

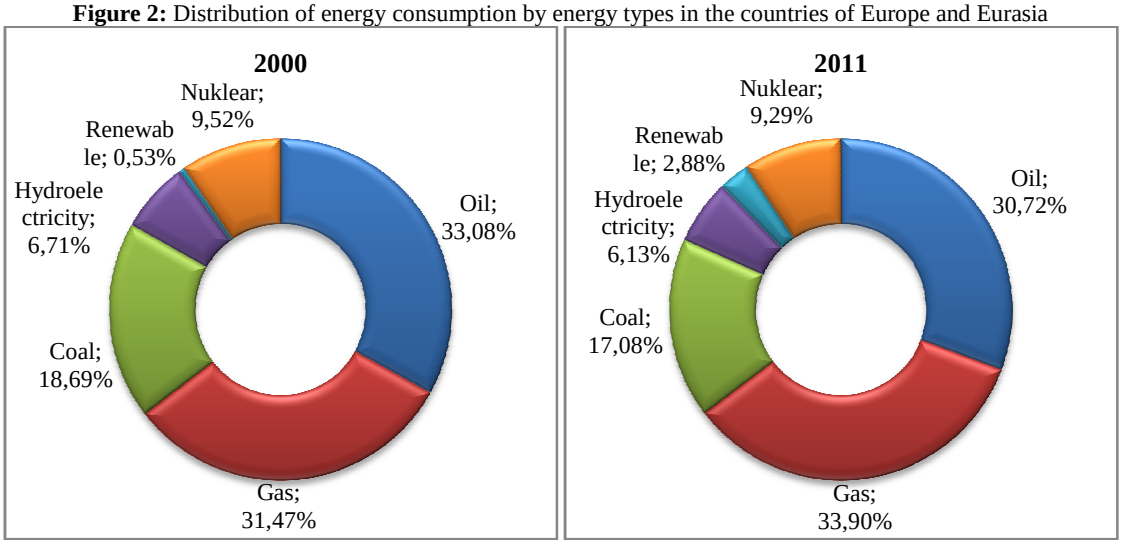
Figure 1: Energy dependence in the countries of Europe in 2011, in %



Source: Own edition, Eurostat

The European Union is responsible for 13,8% of the total energy consumption of the world. The rate of energy dependence has been standing at an almost stable 54% since 2008 and it will likely grow in the next years. The average energy dependence of the EU in 2011 was 53,84% (Figure 1). 14 out of the 27 member countries - that is half of member countries - have higher energy dependence therefore they need to import in order to meet their energy needs. The following countries are the most dependent on import: Malta, Luxembourg, Cyprus, Ireland, Lithuania and Italy. Countries which are the least dependent: Denmark, Estonia, Romania, the Czech Republic and the Netherlands. Out of the 27 EU member states, only Denmark can do without energy import, it is even able to export. Its energy dependence rate was -8,46% in 2011. Its energy consumption has declined by 6% between 2008 and 2011.

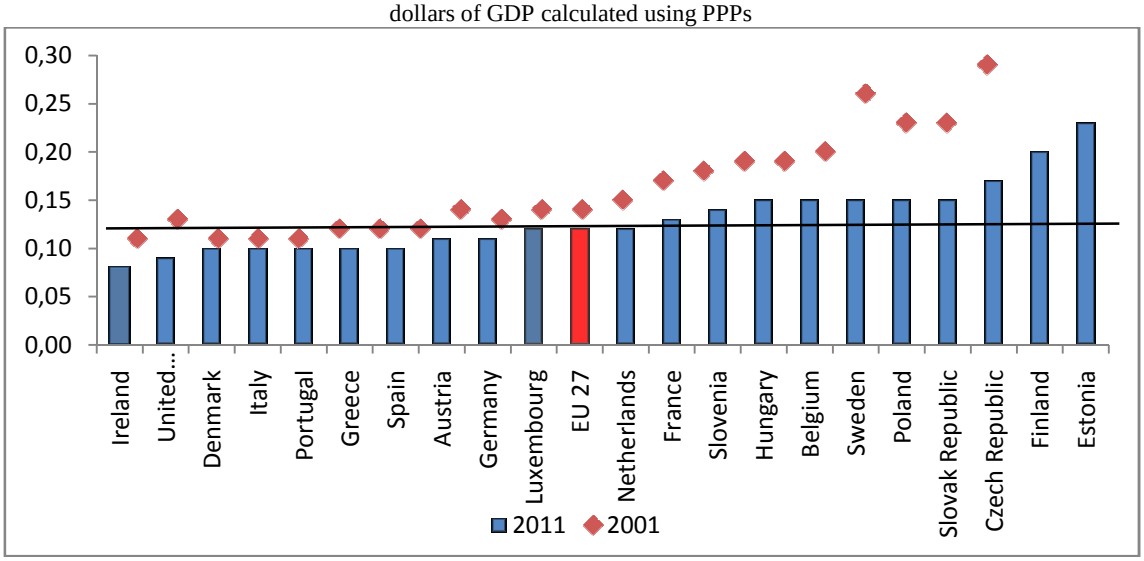
Figure 2: Distribution of energy consumption by energy types in the countries of Europe and Eurasia



Source: Own edition, BP Statistical Review of World Energy June 2012

The structure of energy consumption in the European Union was different in 2011 compared to 2000 (Figure 2). Oil consumption decreased by 2,35% and coal consumption by 1,61%. The use of nuclear energy and hydroelectric energy slightly reduced, too. Natural gas consumption increased by 2,43% and substantial expansion went on in the use of renewable energy sources for energy purposes.
The energy dependence is expected to increase in the European Union by 2050. The oil and coal consumption will further decline. Gas consumption will be reduced to a lesser extent. The use of nuclear energy and hydroelectric energy increases and the use of renewable energy sources will probably grow, too. [Energy roadmap 2050].

Figure 3: Total primary energy supply per unit of GDP in the EU, Tonnes of oil equivalent (toe) per thousand 2005 US dollars of GDP calculated using PPPs



Source: Own edition, OECD Factbook 2013

The energy intensity index helps to measure and compare the energy intensity of different countries, as well as to demonstrate the changes over time. The energy intensity index quantifies the energy required for the production of one GDP unit. In comparison of energy intensity index the national characteristics of different countries should also be considered, like for example population density, size of country, average temperature and structure of economy (the ratio of heavy and light industry in the given country). The decline of the index may reflect the restructuring of the country, too. If, for example, the value of the index is decreasing in the given country because it outsources the activities which require more energy.
The energy intensity was the most favourable in Slovakia in 2011 compared to 2001. Significant improvement was reached in energy intensity by the Czech Republic and Estonia, too. The most energy intensive countries are Ireland, the United Kingdom and Denmark. The least energy intensive countries are the Czech Republic, Finland and Estonia. The positive tendency of energy intensity in Ireland was due to the economic restructuring towards the high added value but low energy-consuming sectors. Another reason was the efficiency of energy production and that economic expansion exceeded the growth of energy consumption. The improving energy intensity was also due to economic restructuring in England and Denmark. In these two countries, changes were implemented in processing industry sectors and they improved the service sector. [EEA, 2013].
A number of papers deals with the analysis of energy consumption. Dushko et al (2011) use regression analysis to examine the impact of global energy production and consumption on population and growth per head. Their results confirm that the GDP per head declines by

0,57% if the energy consumption increases by 1%. If energy production grows by 1%, the GDP increases by 1,51%.
Stocker et al (2011) and Delgado (2008) highlight in their paper that the use of renewable energy sources play an important role in reducing dependence on fossil energy sources, as well as in decreasing the emission of greenhouse gases and in the fight against climate change.
Dernbach (2008) underlines that energy efficiency can be achieved primarily by the decline of energy consumption. Considerable economic, safety, environmental and social advantages are resulted by the improvement of energy efficiency. He also notes that technological innovation, legislative and institutional arrangements are also needed to achieve this. He also deals with the expansion of using renewable energy sources. He regards renewable energy sources as the type of energy which grows the quickest and used in the smallest quantities. He forecasts the increase of renewable energy by 50% by 2030, which can be due to state support.

MATERIAL AND METHOD

The principal component analysis (PCA) is one of the simplest multivariate statistical methods. The examination always starts from observation units (at present these are the countries of Europe and some Eurasian countries) and the typical observation variables (at present these are as follows: oil consumption in million ton, use of gas, coal, hydroelectric energy, renewable energy and nuclear energy in million tons of oil equivalent). The basic data come from the database of BP Statistical Review of World Energ June 2012. The principal component analysis was carried out with the help of Minitab 16 statistical software. The data of primary energy consumption of the examined countries in 2011 are included in Table 1.

Table 1: Primary energy consumption of the examined countries in 2011 by energy types

No.	Countries	Oil (M t)	Gas (Mtoe)	Coal (Mtoe)	Hydroelectric energy (Mtoe)	Renewable energy (Mtoe)	Nuclear energy (Mtoe)
1.	Austria	12,48	8,53	2,48	6,85	1,64	0,00
2.	Azerbaijan	3,60	7,34	0,00	0,61	0,00	0,00
3.	Belarus	8,98	16,47	0,00	0,00	0,00	0,00
4.	Belgium & Luxembourg	33,72	14,45	2,07	0,00	2,07	10,94
5.	Bulgaria	3,53	2,63	8,44	0,64	0,27	3,69
6.	Czech Republic	9,10	7,57	19,17	0,63	1,11	6,40
7.	Denmark	8,29	3,76	3,21	0,00	3,44	0,00
8.	Finland	10,48	3,20	3,32	2,81	2,58	5,31
9.	France	82,93	36,31	9,02	10,31	4,30	100,03
10.	Germany	111,55	65,28	77,55	4,41	23,18	24,44
11.	Greece	17,19	4,08	7,32	0,97	0,90	0,00
12.	Hungary	6,49	9,14	2,73	0,05	0,66	3,55
14.	Italy	71,13	64,21	15,42	10,07	7,73	0,00
15.	Kazakhstan	10,19	8,31	30,18	1,79	0,00	0,00
16.	Lithuania	2,72	3,06	0,20	0,24	0,14	0,00
17.	Netherlands	50,07	34,25	7,80	0,00	2,73	0,94
18.	Norway	11,13	3,62	0,65	27,62	0,40	0,00
19.	Poland	26,31	13,82	59,77	0,62	2,24	0,00
20.	Portugal	11,60	4,60	2,59	2,77	2,83	0,00
13.	Republic of Ireland	6,85	4,21	1,26	0,16	1,07	0,00
21.	Romania	9,04	12,46	7,07	3,40	0,22	2,66
22.	Russian Federation	136,01	382,11	90,93	37,32	0,11	39,15
23.	Slovakia	3,71	5,62	3,25	0,92	0,14	3,43
24.	Spain	69,48	28,93	14,88	6,92	12,67	13,04
25.	Sweden	14,47	1,13	1,96	15,04	4,10	13,82
26.	Switzerland	11,04	2,62	0,14	7,37	0,33	6,10
27.	Turkey	31,99	41,17	32,45	11,85	1,34	0,00
28.	Turkmenistan	4,93	22,47	0,00	0,00	0,00	0,00
29.	Ukraine	12,90	48,30	42,37	2,44	0,00	20,42
30.	United Kingdom	71,61	72,18	30,82	1,29	6,63	15,62
31.	Uzbegistan	4,37	44,23	1,33	2,31	0,00	0,00

Source: Own edition, BP Statistical Review of World Energy June 2012

The data concerning renewable energy consumption include the use of wind, geothermic, solar energy as well as energy produced of biomass and wastes. Some renewable energy sources are not available in some member countries – due to their conditions. Such as for example tidal and wave energy which can be used by member countries with seashores. Geothermal energy also depends on natural conditions. The EU directive defines hydroenergy as renewable independently from capacity. BP, however, ranks the use of hydroelectric energy in different group in the measuring of energy consumption.

In the frames of PCA those principal component variables can be regarded significant, the eigenvalue of which (variance and standard deviation) is above the average, that is higher than one. Another rule concerning the significance of principal component variables says that as many principal component variable can be regarded considerable as together explain at least 80% of total variance.

The ***U*** matrix of principal component coefficients help to determine which observation variables are in close relation with individual principal component variables. The coefficients with high absolute value indicate strong dependence on the examined principal component variable. As regards the original observation variables it can be concluded that the observation variables strongly depending on the same principal component variable form a mutually correlated variable group. The signs of coefficients indicate the direction of relations between variables.

RESULTS

Table 2 shows the correlation between the consumption of energy types. The underlined figures in the table refer to a moderately strong or strong correlation.

Table 2: Correlation matrix of energy consumption

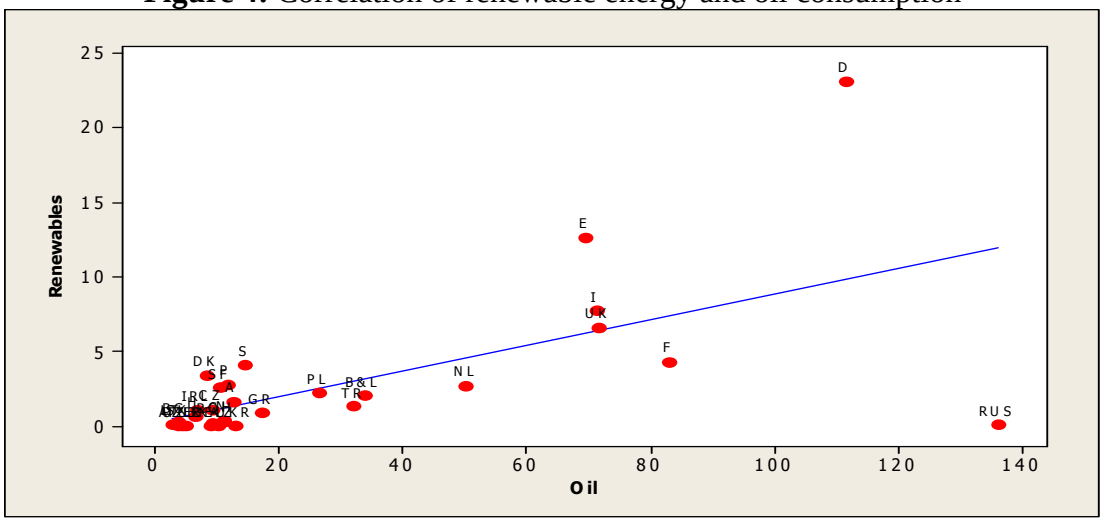
Energy consumption	**Oil**	**Gas**	**Coal**	**Hydroelectric energy**	**Renewable energy**	**Nuclear energy**
Oil	1	0,74064	0,71140	0,51821	0,62781	0,60018
Gas		1	0,70829	0,68725	0,07626	0,36996
Coal			1	0,40372	0,41066	0,29734
Hydroelectric energy				1	0,01714	0,34209
Renewable energy					1	0,24227
Nuclear energy						1

Source: Own calculation

The data of consumption are always in positive relation with each other. There is close relation between the use of oil and gas, oil and coal as well as gas and coal. Moderately strong relation can be seen between the consumption of oil and hydroelectric energy, oil and renewable energy, oil and nuclear energy, as well as gas and hydroelectric energy. The weakest is the relation between the renewable energy and hydroelectric energy as well as renewable energy and gas consumption.

Some kind of an energy source is needed for the production of renewable energy sources. The consumption of renewable energy is mostly in weak relation with the consumption of other primary energy. Oil consumption is in the closest relation with the use of renewable energy. Figure 4 indicates that there is a moderately strong linear relation between the consumption of these two types of energy. The correlation is weak and the direction is positive between coal and renewable energy consumption (Figure 5). There is no relation between the consumption of renewable energy and hydroelectric energy (Figure 6). The correlation between them is negligible.

Figure 4: Correlation of renewable energy and oil consumption



Source: Own edition, Minitab 16

Figure 5: Correlation of renewable energy and coal consumption

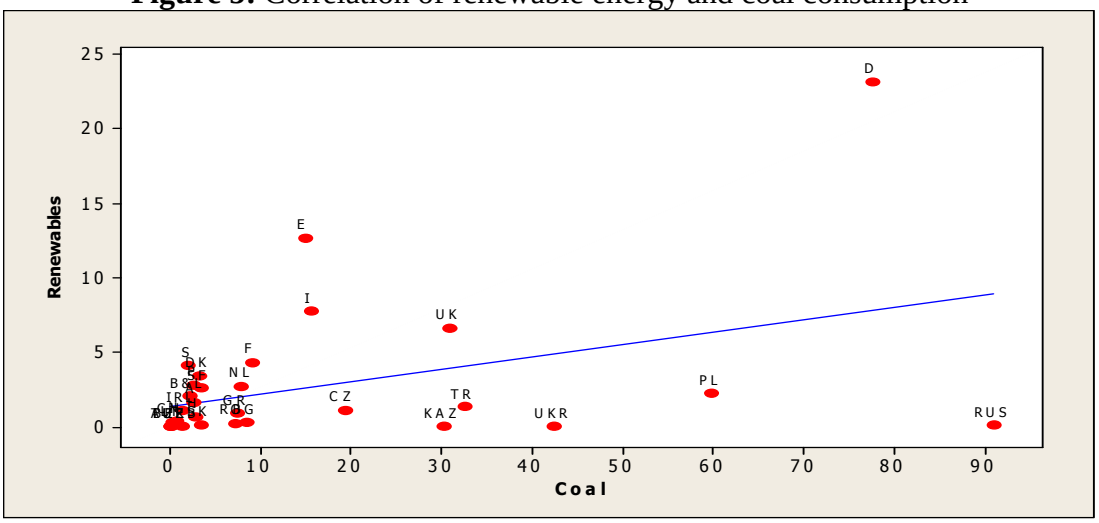


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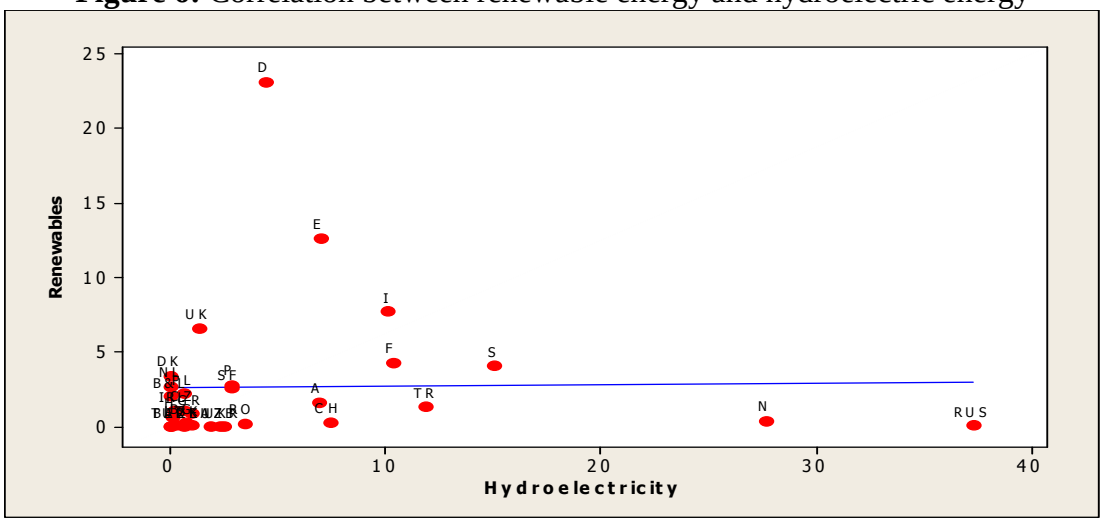
Figure 6: Correlation between renewable energy and hydroelectric energy



Source: Own edition, Minitab 16

Table 3: Eigenvalue, explanatory ratio and cumulative explanatory ratio of principal components

Variables	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Eigenvalue	3,3729	1,1746	0,7653	0,4410	0,2068	0,0395
Proportion	0,5620	0,1960	0,1280	0,0730	0,0340	0,0070
Cumulative	0,5620	0,7580	0,8850	0,9590	0,9930	1,0000

Source: Own calculation, Minitab 16

Out of principal component variables those can be regarded significant the eigenvalue of which is higher than one, and those principal components which together explain at least 80% of the total variance. The role of other principal components is insignificant.
In our case the first two principal components can be regarded significant on the basis of eigenvalue (Table 3), which explain 75,80% of the total variance. Therefore the second criteria is almost fulfilled on the basis of the first two principal components.

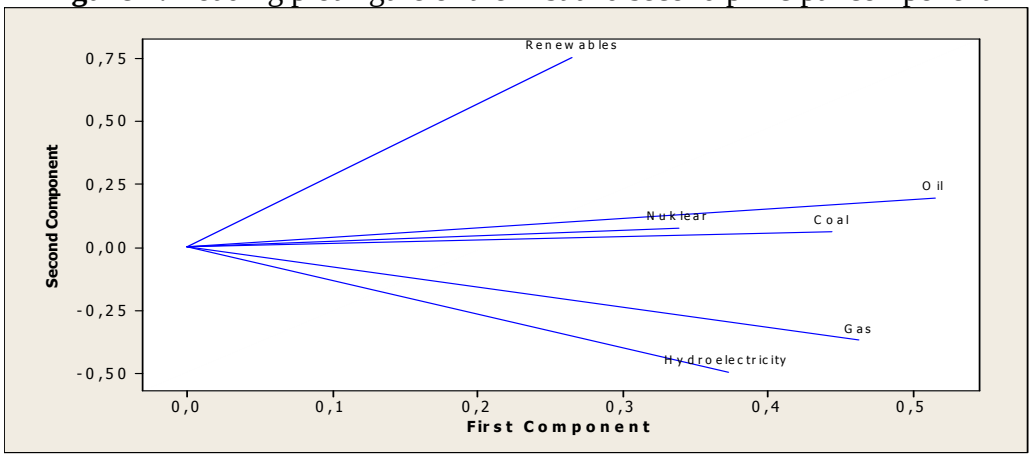
Table 4: ***U*** matrix of principal component coefficients

Energy consumption	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Oil	0,5147	0,1969	0,0344	0,0506	0,4339	-0,7101
Gas	0,4625	-0,3689	-0,2011	-0,2011	0,5326	0,5343
Coal	0,4441	0,0633	-0,4523	-0,4704	-0,6046	-0,0854
Hydroelectric energy	0,3727	-0,4963	0,0498	0,6973	-0,3536	-0,0315
Renewable energy	0,2652	0,7542	-0,1242	0,4152	-0,0150	0,4157
Nuclear energy	0,3387	0,0771	0,8578	-0,2776	-0,1930	0,1707

Source: Own calculation, Minitab 16

The principal component coefficients indicate the significance of principal component variables in regard to the value of observation variables.
In case of the first principal component the consumption of coal, gas and oil can be considered significant (Table 4). These variables form a mutually correlating variable group. The direction of relation among them is positive. The first principal component can be titled as the consumption of fossil energy types. On the basis of the coordinate of B1 principal component coordinate in Table 5 it can be declared that Germany, Russia and the United Kingdom consumes much more oil, gas and coal than the average.
In case of B2 second principal component the consumption of renewable energy and hydroelectric energy in the opposite direction can be regarded significant. Therefore in those countries where the consumption of renewable energy is above the average, the use of hydroelectric energy is below the average. The second principal component can be called alternative energy use. In case of Germany, Spain and the United Kingdom the coordinate values of B2 second principal component are positive, which indicate high renewable energy use, while the coordinates are negative in case of Russia, Norway and Turkey, which have high hydroelectric energy use.

Figure 7: Loading plot figure of the first and second principal component



Source: Own edition, Minitab 16

Figure 7 leads to the same conclusion. The first principal component is positively correlated with all the six types of energy. There is a strong positive relation between the consumption of oil, gas and coal. The second principal component is in strong positive relation with renewable energy, and strong negative relation with hydroelectric energy use, as well as with natural gas use.

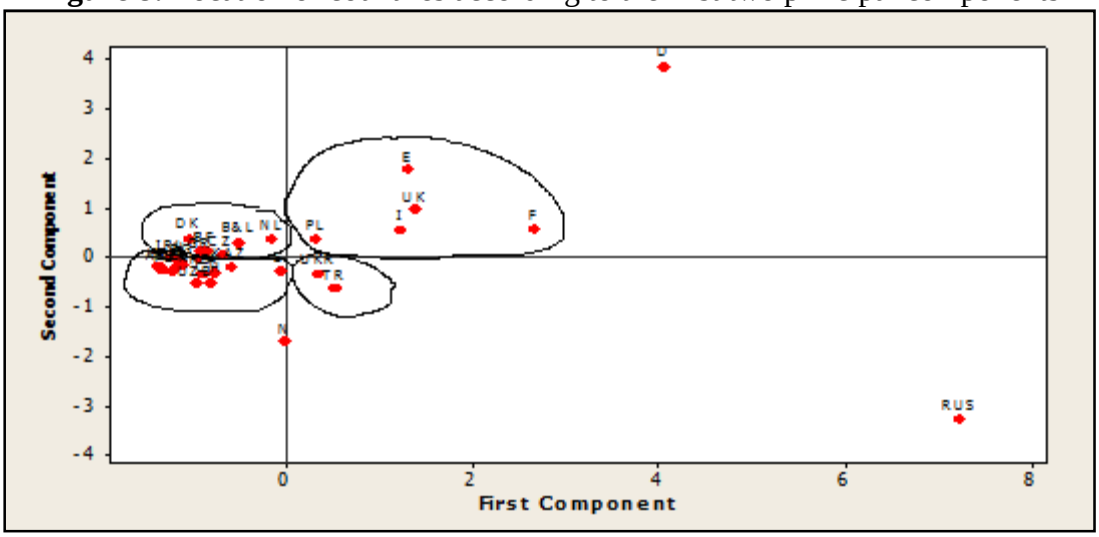
Table 5: ***B*** matrix of coordinates in case of principal components which can be regarded significant

No.	Countries	B1	B2
1.	Austria	-0,7683	-0,2998
2.	Azerbaijan	-1,3245	-0,2451
3.	Belarus	-1,2092	-0,2280
4.	Belgium & Luxembourg	-0,5058	0,3046
5.	Bulgaria	-1,1152	-0,1419
6.	Czech Republic	-0,7002	0,0392
7.	Denmark	-1,0511	0,3957
8.	Finland	-0,8506	0,1295
9.	France	2,6590	0,5922
10.	Germany	4,0520	3,8474
11.	Greece	-0,9381	-0,0079
12.	Hungary	-1,1421	-0,0784
13.	Republic of Ireland	-1,2329	-0,0093
14.	Italy	1,2129	0,5522
15.	Kazakhstan	-0,5937	-0,2010
16.	Lithuania	-1,3711	-0,1823
17.	Netherlands	-0,1587	0,3708
18.	Norway	-0,0066	-1,7100
19.	Poland	0,3202	0,3684
20.	Portugal	-0,9198	0,1476
21.	Romania	-0,8915	-0,3418
22.	Russian Federation	7,2348	-3,2581
23.	Slovakia	-1,1907	-0,2088
24.	Spain	1,3080	1,7604
25.	Sweden	-0,0544	-0,2846
26.	Switzerland	-0,8173	-0,4981
27.	Turkey	0,5173	-0,6267
28.	Turkmenistan	-1,2289	-0,2835
29.	Ukraine	0,3374	-0,3247
30.	United Kingdom	1,3918	0,9588
31.	Uzbekistan	-0,9627	-0,5366

Source: Own calculation, Minitab 16

The energy consumption of some countries according to the first two main components can be described with the help of principal components of Table 5 (Figure 8).

Figure 8: Location of countries according to the first two principal components



Source: Own edition, Minitab 16

The examined countries can be ranked in four groups on the basis of representing the first two components in a coordinate system.

The first group includes those countries, where the consumption of fossil energy sources is not extremely high and they also use renewable energy sources in small quantities. These countries are: the Netherlands, Denmark, Finland, Portugal, Belgium, Luxembourg and the Czech Republic.

The second group consists of those countries where the consumption of fossil energy sources is not too high compared to the average and in addition to these they mostly use hydroelectric energy out of the renewable energy sources. Half of the examined countries belong to this group. These countries are for example: Slovakia, Switzerland, Sweden, Austria and Hungary.

The third group of countries use substantial quantities of fossil energy sources and – in addition to these – mostly hydroelectric energy. These countries are Ukraine and Turkey.

In regard to energy consumption, those countries were put in the fourth group in which the consumption of fossil energy sources is high but they also use renewable energy sources in high quantities. These countries are as follows: Poland, Italy, France, Spain and the United Kingdom.

Those countries where energy consumption is strongly deviates from average were not included in any of the groups. These countries are Norway, Russia and Germany. In case of these observation units, our conclusions from the examination are not always valid. Germany has consumed substantial amount of fossil energy in the examined period and used considerable quantity of renewable energy, too. The outstanding value comes from the fact that they used 8,6-times more renewable energy sources than the average. In case of Russia, the consumption of hydroelectric energy was 7,3-times higher than the average. In addition to this, Russia uses significant amount of fossile energy sources which is justified by the structure of economy as well as weather conditions. Norway can be classified in the second group. Its average fossil energy consumption is higher than in the countries ranked here and its hydroelectric energy use also substantially exceeds the average therefore it could not be put in the second group.

CONCLUSIONS

The paper uses principal component analysis to introduce the primary energy consumption of 31 European and Eurasian countries in 2011. The use of fossil primary energy sources can be regarded low in half of the examined countries. The energy mix of these countries also include renewable energy sources in small quantities. These countries are for example: Ireland, Austria, Slovakia, Hungary and Denmark. Countries with average primary energy source use: Norway, Switzerland, the Netherlands, Belgium and Luxembourg. Those countries use renewable energy sources above the average quantity where the use of fossil energy sources is also higher than the average. These countries are: Germany, France, United Kingdom, Spain and Italy.

On the basis of the energy intensity index it can be concluded that out of the countries of Europe, Western Europe, Ireland and the United Kingdom are the most energy-efficient because these two countries use the least energy for producing one unit of GDP.

The ratio of energy dependence is very high in the countries of Europe. More than half of energy consumption comes from import. By using renewable energy sources the high proportion of energy dependence can be reduced and thus they also contribute to sustainable energy use but energy independence cannot be reached completely with these energy sources and the current technological skills within a reasonable time.

Since the exploitable quantity of available fossil energy sources is permanently diminishing, the efficient and sustainable use of the existing energy could be realized the easiest by reducing energy consumption, changing consumer habits, implementing technological innovation as well as making proper legislative and institutional arrangements.

When we fulfill our energy need, it is important that we cannot endanger the chance of future generations to meet their needs.

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