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Spatio-Temporal Dynamics of the Electric Power Industry Development in European Countries

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Abstract:

Currently the issues of energy and economic security of states are of the utmost importance. The article analyzes the dynamics of the electric power industry development in European countries using the trend and sectoral approaches, geographic systematization and cartographic method. The dynamics of electricity production and consumption in Europe is characterized based on the statistics of the International Energy Agency over the period 1992-2014. It has been shown that European countries differ in trends in the dynamics of electricity production from the end of the 20th to the beginning of the 21st century. Accordingly, they can be divided into 4 groups characterized with the following: 1) steady growth (Germany, France, Austria, Poland, etc.), 2) intensive growth (Italy, Spain, Greece, Ireland, etc.), 3) unstable dynamics (Norway, Switzerland, Denmark, Finland, etc.), 4) fall in production in the early 1990s and further growth (some post-socialist countries). The paper analyzes the change in the sectoral structure of electric power production in Europe as a whole and in certain European countries and reveals the differences in the degree of their electric power independence. These differences are reflected in the division of European countries into electric energy-sufficient and electric energy-deficient ones with prevalence of the latter. The analysis of the sectoral structure of the electric power industry in the countries of the European region has shown a tendency towards diversification and increase in the share of alternative energy sources. Besides, the typology of the electric power industry development level in European countries has been set out. Based on a scoring method and calculation of the integrated index using the indicators that assess: 1) the production and consumption of electricity; 2) the sectoral structure and the efficiency

of the electric power industry functioning, five types of countries have been defined. At present, 10 countries (Germany, France, Sweden, United Kingdom, Spain, Austria, Norway, Russia, Italy and Romania) that have reached a very high level of electric power industry development according to the complex of the studied indicators can be considered as a core of the region. It has been revealed that countries with a high and medium level of the electric power industry development prevail in modern Europe. At the same time, during the period from 1992 to 2014, the share of countries with a very high, high and medium level of the electric power industry development increased, while the number of countries with a low and very low level decreased.

Keywords: electric power industry; electricity independence; renewable resources; alternative energy sources; typology of countries; energy security.

JEL Classification: Q42 ; Q47 ; L94 ; P28.

Introduction

Since the end of the 21st century, the world electric power industry has changed qualitatively due to the increasing use of alternative energy sources (AES). On the one hand, there is a shortage of traditional fuel and energy resources in the European region, on the other, an intensive development of renewable energy sources is observed. Within the framework of the present research the electric power industry development in Europe is analyzed from the point of view of studying the issues of energy and economic security.

Since the 1960s, the interest of scientists in the field has been directed to nuclear power. However, since the late 1970s (after the Three Mile Island accident in the US), particular attention has been paid to the study on "geographical consumption", including behavioral responses, safe power plant siting, democratic principles of nuclear energy development, etc. In the 21st century, there is an increasing tendency towards exploration of the renewable energy geography and territorial organization of energy systems among specialists and scientists from different countries.

De-carbonization of economy is a solution to a current problem of decreasing the carbon intensity of GDP. According to forecasts, by 2050, at least 50% (according to some estimates up to 70%) of electricity in the world will be produced from renewable energy sources (Tarlawski 2015). In some scientific papers, the shifts in the energy structure in favor of renewable sources (wind energy and biomass) are considered as a basis for territorial reorganization of economic relations (Calvert 2013).

Besides, studies in the field of estimating the cost of electric power infrastructure in different countries (Senyel 2013, Simon 2007) are of special scientific interest. A great contribution to the scientific direction studying the development of modern electric power industry is made by scientific articles devoted to certain aspects of the renewable energy sources use in the USA (Mai 2014), European countries (Lofstedt 2008, Rodionova, Shuvalova 2011), and the Russian Federation (Chernyaev 2014). Issues on the electric power industry development of European countries are considered in detail in research works by Zhigalskaya L.O. (Zhigalskaya 2016).

The share of renewables in electricity generation in Europe is still low, however, there is a political will to develop solar and wind energy and electricity generation from biogas in the future (Torrijos 2016). It is emphasized that the production of biogas from solid waste is developing in Europe, but there are significant differences between countries. Some papers are devoted to the characteristic of current situation and future prospects of the bioenergy development in Poland (Igliński *et al.* 2011, Budzianowski 2012) and in other countries of the Visegrad Group – the Czech Republic, Hungary and Slovakia (Chodkowska-Miszczuk *et al.* 2017). As it is noted in the articles and monographs, politicians and the public in Europe have different opinions on nuclear and renewable energy development. Thus, some countries (*e.g.* Austria, Denmark) which do not currently have nuclear power consider renewable energy sources as an effective way to reduce carbon dioxide emissions into the atmosphere. Other countries (for example, Slovakia) which are less endowed with renewable energy resources, consider nuclear power as the electricity generation source which will help not only to reduce dependence on import of fossil fuel, but also to reduce emissions of CO₂ (Lofstedt 2008). In other words, all researches about the use of alternative energy sources are directly connected with the topic of energy security of countries. The concept of energy security includes all the risks influencing on the energy supply (Winzer 2012, Umbach 2010, Boie *et al.* 2014), including the relations in energy sector between Russia and other countries in Europe (Harsem 2013). In particular, European countries intend to reduce emissions of carbon dioxide (CO₂) by more than 80% by 2050 (as compared to the level

of 1990) by means of the growing share of renewable energy sources in electricity generation, and to increase energy efficiency by 20% till 2020. Thus, it is emphasized that the use of renewables has considerably increased in the EU, and it will grow further. The principles of renewables integration into modern and future energy infrastructures are characterized from the point of view of national and regional features of European countries (Boie *et al.* 2014). One of the monographs investigates stages of solving the energy security problem in Germany in the historical context, analyzes legislation in the field of the use of renewable resources, and characterizes features of subsidizing certain branches of alternative energy in this highly developed European country (Sumin 2017).

It is worth mentioning that the idea of possibility of carbon-free economy development was first described by the Danish physicist B. Sorensen in 1975, who offered the plan of Denmark transition to a 100% electricity generation on wind and solar power facilities (Sorensen 1975). In 1976, the American physicist, ecologist and ideologist of the “green movement” E. Lovins introduced the term “soft energy path”, which means the process of replacing thermal and nuclear energy with renewable energy following the principle of energy efficiency (Lovins 1976). Many researchers have written about the optimal combination of traditional and renewable energy sources (Lund 2005, Sumin 2017; etc.).

There have been a lot of reasons causing significant structural and spatial shifts in electric power industry in recent decades. It is connected with global changes in world economy, in particular, with the entry into a new stage of development – the post-industrial one, with processes of internationalization of the world economic system, with cardinal change in the principles of organization and management in the electric power industry. The structure of raw materials base is changing; the production technologies are being improved. More attention is paid to environmental problems and opportunities for implementing the principles of sustainable development Rio+20.

The above-listed processes define relevance of the analysis of the key aspects of the electric power industry development in European countries. The study of these aspects will reveal the differences between the countries of Europe in terms of the level of the electric power industry development.

The purpose of this study consists in carrying out a spatio-temporal analysis of the electric power industry development in Europe and setting up the typology of European countries in terms of the level of the electric power industry development in order to identify regional patterns of the industry development from 1992 to 2014.

1. Methods

The methodological basis for the typology of European countries in terms of the level of the electric power industry development in our study was the classification of the economic regions of the USSR in terms of the development of the electric power industry, which was made by Russian scientists V. Gorlov and V. Baburin based on the analysis of reporting data and calculation of electrical balances (Gorlov 1982). Trends in the dynamics of electricity production and consumption in Europe over the past 20 years were identified on basis of research works written by I. Rodionova where conclusions about structural and territorial shifts characteristic of different industries, including electric power industry, are given (Rodionova 2014, Rodionova, Chernyaev, Korenevskaya 2017).

The information base of the study was the official statistical materials of the International Energy Agency (IEA), U.S. Energy Information Administration (EIA) and BP Statistical Review of World Energy.

All countries of Northern, Western, Southern and Eastern Europe (including three countries of the Commonwealth of Independent States – Russia, Ukraine, Belarus) have been referred to the European region in our research. A comparative geographical analysis of the development of the electric power industry in European countries over the period from 1992 to 2014 was carried out. The calculation of the integral index of the electric power industry development level was made by key years: 1992, 2000, 2014 (index calculation was performed for 39, 40 and 42 countries, as the number of countries increased due to the collapse of the USSR, Yugoslavia, etc.).

At the *first stage* of this research, the differentiation of the countries was revealed in accordance with the industry development trends. It is based on the analysis of the dynamics of electricity production and consumption in European countries and calculation of the production growth rate over the period from 1992 to 2015. Electricity balance of European countries was analyzed using the index of electricity independence (*I_{eI}*), which represents the ratio of electricity production volume to the volume of electricity consumption.

Based on the calculations the typology of the countries was set up. The first type is represented by the electricity-sufficient countries (the index value is more than 100 %). They were divided into two subtypes: a). balanced (from 100 to 125%) and b) abundant (more than 125 %). The second type is represented by the electricity-deficient countries (index of electricity independence value is less than 100 %).

The *second stage* included an analysis of changes in the electric power industry structure in Europe (and certain countries in the region). The calculations of the structure of the electric power industry of the European countries during 1990 – 2014 were carried out. It made possible to distinguish three types of countries in terms of the structure of the electric power industry:

- mono-specialized structure;
- combined structure;
- diversified structure.

The *third stage* of the research is the systematization (typology) of European countries in accordance with the electric power industry development level, based on the indicators system study and integral index calculation. As a result, 9 indicators were selected and integrated into 3 groups, which characterize various aspects of the electric power industry development:

- production and consumption of electricity;
- the sectoral structure of electric power industry;
- the industry efficiency.

The first group is represented by four indicators:

- electricity generation (I_1);
- electric power independence (I_2), *i.e.* the ratio of the volume of electricity production ($V_{prod.}$) to the volume of electricity consumption ($V_{cons.}$) (Formula 1):

$$I_2 = \frac{V_{prod.}}{V_{cons.}} \times 100\% \quad (1)$$

- electric power system capacity (I_3);
- import ($V_{imp.}$) share in electricity consumption (I_4) (Formula 2):

$$I_4 = \frac{V_{imp.}}{V_{cons.}} \times 100\% \quad (2)$$

The second group includes two indicators:

- number of electrical energy sources (I_5), which allows for determining the diversification of the industry structure;
- electricity generation from renewable energy sources (RES) (V_{RES}) – the share of the general production (I_6) (Formula 3):

$$I_6 = \frac{V_{RES}}{V_{prod.}} \times 100\% \quad (3)$$

The third group consists of three indicators:

- electricity consumption per gross domestic product (GDP) (I_7) (Formula 4):

$$I_7 = \frac{V_{cons.}}{GDP} \quad (4)$$

- electricity consumption per capita (I_8), *i.e.* the ratio of the volume of consumed energy to the average annual population (N) in the country (Formula 5):

$$I_8 = \frac{V_{cons.}}{N} \quad (5)$$

- electric power transmission and distribution losses (ΔW), % of output (I_9) (Formula 6):

$$I_9 = \frac{\Delta W}{V_{prod.}} \times 100\% \tag{6}$$

An integral index of the electric power industry development level of the country (I_{EDL}) for subsequent economic-geographical comparison was created using the scoring method, in accordance with which a five-point system was proposed for estimating each indicator in the geographic information system ArcGIS by the Jenks natural breaks classification method (Table 1).

The integral index includes 3 components in accordance with groups of indicators and is defined as their average arithmetic value (Formulas 7, 8, 9, 10):

$$I_{EDL} = \frac{(I_1 \text{ gr.} + I_2 \text{ gr.} + I_3 \text{ gr.})}{3}, \tag{7}$$

where:

$$I_1 \text{ gr.} = \frac{I_1 + I_2 + I_3 + I_4}{4} \tag{8}$$

$$I_2 \text{ gr.} = \frac{I_5 + I_6}{2} \tag{9}$$

$$I_3 \text{ gr.} = \frac{I_7 + I_8 + I_9}{3} \tag{10}$$

Each indicator was assigned a score (Table 1) depending on the calculated characteristics (from 1 to 5). Further, the integral index was calculated.

Depending on the value of the integral index the rating of countries of the European region was compiled, according to which five levels of the electric power sector development were determined:

- 1) very high (the value of integral index from 3.51 and higher);
- 2) high (3.01 – 3.50);
- 3) medium (2.51 – 3.00);
- 4) low (2.01 – 2.50);
- 5) very low (2.00 or less).

The mapping of the obtained results was carried out using the methods of graphic visualization of socio-economic processes in ArcGIS.

Table 1. Parameters and scoring system for characterizing the electric power industry development level in European countries

Group of indicators	Indicator	Unit of measurement	Scores				
			1	2	3	4	5
Group 1 (indicators characterizing the production and consumption of electricity)	Electricity generation (I_1)	TWh	less than 30	31 – 100	101–300	301 – 500	more than 501
	Electric power independence (I_2)	%	less than 50	51 – 100	101–110	111 – 125	more than 126
	Electric power system capacity (I_3)	GW	less than 10	11 – 20	21–50	51 – 100	more than 101
	Import share in electricity consumption (I_4)	%	more than 61	41 – 60	21 – 40	11 – 20	less than 10
Group 2 (indicators characterizing the electric power industry structure)	Number of electrical energy sources (I_5)	Unit	1 – 2	3	4	5 – 6	7 – 8
	Share of electricity generation from renewable energy sources (I_6)	%	less than 10	11 – 20	21 – 35	36 – 70	more than 71
Group 3 (indicators characterizing the efficiency of the electric power industry)	Electricity consumption per GDP (I_7)	kWh/1000 USD	more than 501	351–500	251–350	201 – 250	less than 200
	Electricity consumption per capita (I_8)	MWh/capita	less than 2.5	2.6–5.0	5.1–7.5	7.6 – 10.0	more than 10.1

Group of indicators	Indicator	Unit of measurement	Scores				
			1	2	3	4	5
	Electric transmission power and distribution losses (I_b)	%	more than 20.1	13.1-20.0	9.1-13.0	6.1 – 9.0	less than 6.0

Source: calculated by the authors

2. Results

Dynamics of Production, Consumption and Electricity Independence of European Countries. A tendency towards constant growth in annual electricity production is observed in the world. Over the period 1992 – 2016, electricity production increased from 12.2 to 24.8 mln GWh. This trend is also typical for European countries. However, during more than 20 years, electricity generation in the region has increased from 3.9 mln GWh to 4.6 mln GWh or by 33 %. Such dynamics scale is also peculiar to North American Countries. These regions have the same share in the world electricity production. Other regions have demonstrated an unprecedented growth in electricity production since the end of the twentieth century. (Table 2).

A stable group of countries leading in electricity production has been formed in Europe – Russia (1087 TWh), Germany (648), France (553), Great Britain (339), Italy (286 TWh) (BP Statistical Review, 2016). Their total share is 60 % of total electricity generation in Europe. Electricity production in Spain (274 TWh), Poland (167), Ukraine (164), Sweden (155) and Norway (149.5 TWh) is higher than the average European level. In addition, the majority of European countries produce less electric power than the average value in Europe. It does not exceed 30 TWh (Lithuania, Hungary, Ireland, Slovakia, etc.).

Table 2. Dynamics of electricity production

Regions	Production, mln GWh			Share in world production, %			Change from 1992 to 2016, %
	1992	2000	2016	1992	2000	2016	
North America	3.9	4.8	5.3	32	31	21.5	36
Central and South America	0.5	0.8	1.3	4	5	5.3	160
Europe and Eurasia	4.6	4.7	5.4	38	31	21.7	17
Middle East	0.2	0.5	1.1	2	3	4.4	450
Africa	0.3	0.4	0.8	2	3	3.2	167
Asia and Oceania	2.7	4.2	10.9	22	27	43.9	304
World	12.2	15.4	24.8	100	100	100	103

Source: calculated by the authors based on BP Statistical Review of World Energy 2016

There are clear regional differences in electricity production per capita in Europe. The most electricity is produced in Northern Europe (8.0 kWh per capita), followed by Western Europe (7.7), and the smallest rate of electricity generation per capita is noted in Eastern (5.6) and Southern (4.9) Europe.

European countries differ in trends in the dynamics of electricity production during the period 1990 – 2014. They can be divided into 4 groups characterized with the following:

- steady growth (Germany, France, Austria, Poland, etc.);
- intensive growth (Italy, Spain, Greece, Ireland, etc.);
- unstable dynamics (Norway, Switzerland, Denmark, Finland, etc.);
- fall in production in the early 1990s and further growth. The fourth group is represented by certain post-socialist countries (Russia, Ukraine, Moldova, Bulgaria, Romania, Belarus). The group of countries leading in consumption coincides with the group of countries leading in electricity production.

According to the index of electrical power independence (I_{ei}), we revealed the differentiation among the countries in terms of electrical power balance. On the basis of calculations, European countries are divided into two types: the first type includes electricity-sufficient countries (index value – more than 100%), which, in turn, are divided into two subtypes – balanced (from 100 to 125%) and abundant (more than 125%); the second type is

represented by electricity-deficient countries (index of electricity independence value – less than 100%). In 1992, the group of electricity-sufficient countries dominated in total structure and its share in relation to the second type was 73% to 27%. The balanced subtype includes Germany, France, United Kingdom, and Poland, the abundant subtype – Norway and Czech Republic.

From 1992 to 2014, there was a general trend towards an increase in the share of electricity-deficient countries (the second type) from 27% to 38%. This type is represented by some transition countries in Central and Eastern Europe (Montenegro, Macedonia, Latvia, Lithuania, Hungary, Croatia, etc.), as well as a number of states in Northern and Southern Europe.

Electric power industry sectoral structure dynamics in European countries shows a diversification of energy sources and increase in renewables in the overall electricity balance.

Reduction in industrial use of oil, gas and coal becomes the essence of the new energy policy of advanced countries. It is a long-term global trend in the “green economy” development. In 2014, EU leaders set climate and energy targets to be achieved by 2030, promised to reduce domestic emissions of greenhouse gases by 40%, to stop using fossil fuels and decarbonize national economies during the 21st century. It means that the role of hydrocarbon energy will gradually decline (Tarlawski 2015).

In 1990, 61% of electric power in Europe have been produced at thermal power stations (TPS), 22% – at nuclear power stations (NPS), about 17% – using renewables (15.9% – at hydroelectric power stations (HPS) and 0.6% – on electric generating plant using alternative energy sources). For 24 years the structure of electricity production has changed dramatically. The share of TPS decreased to 41%, the share of NPS increased to 22%, and the share of RES went up to 22%. At the same time, the share of hydroelectricity production has not changed fundamentally, but electricity generation from alternative energy sources has grown significantly (Table 3).

Table 3. Dynamics and structure of electricity production in Europe

Indicator	1990	1995	2000	2005	2010	2014
Electricity production (TWh)	4273.54	3835.28	4131.30	4471.01	4640.41	5098.96
Fossil fuels (%)	61.01	54.36	53.42	54.34	52.31	41.07
Hydro (%)	15.93	18.00	17.72	15.36	160.04	14.99
Nuclear (%)	22.47	26.55	26.93	26.54	24.50	21.80
Geothermal (%)	0.08	0.10	0.15	0.17	0.23	11.30
Wind (%)	0.02	0.11	0.54	1.58	3.23	5.04
Solar (%)	0.00	0.00	0.00	0.03	0.50	1.94
Tide and wave (%)	0.01	0.01	0.01	0.01	0.01	0.01
Biomass and waste (%)	0.47	0.86	1.23	1.97	3.19	3.85

Source: compiled by the authors based on International Energy Agency data

The structure of consumed fossil fuel at TPS is gradually changing: the share of oil products is declining, the share of natural gas is rising, but coal is still the main fuel for TPS in a number of European countries.

Countries leading in electricity production in 2014 are: Russian Federation (679 TWh), Germany (350), United Kingdom (232), Italy (190), Poland (136 TWh) and Spain (136 TWh). Leading hydropower producers in Europe are: Russian Federation (183 TWh), Norway (129), and France (76 TWh). The main producers of nuclear energy are: France (424 TWh), Russian Federation (173), and Germany (97) (Key World Energy STATISTICS, 2015).

The six leading producers of thermoelectric power generate 72% of total production in Europe (the share of three leading countries is 60%). The share of the three states leading in the production of nuclear energy is 62%. The share of the three hydroelectric power producers is 50%.

The prevalence of TPS is observed in Belarus, Moldova, Malta, Cyprus, Poland and Estonia (their share is about 90%). Nuclear power production traditionally dominated in France (76% of total electricity production), Belgium (50%) and Slovakia (54%).

The prevalence of renewables (including hydropower plants) is observed in about 25% of countries in the European Region, while in Iceland and Albania their share is 100%. If earlier the RES share up to 25% in the

structure of electricity generation had been presented in 12 countries, their quantity has increased almost twice (21 states).

Countries differentiation makes it possible to distinguish three types of states in the structure of electricity production. The first type is presented by countries with a mono-specialized structure (one type of power plant produces more than 75% of electricity). The second type includes countries with a combined structure (50 – 75% of electrical energy is produced by one type of power plant). The first and second types can be divided into subtypes depending on the variety of dominant power plants. The countries where less than 50% of total electricity is produced by various types of power plants belong to a diversified type of structure.

Generally, 51% of the countries form a combined type, more than every third state (32%) have a mono-specialized type, and 16% of the countries are characterized by a diversified structure. At the same time, the subtype of countries with a combined structure was identified based on the use of alternative energy sources (e.g. Denmark).

Structural and Geographical Shifts in Alternative Electric Power Industry in Europe. Europe had been the world historical leader in electricity generation using alternative energy sources till 1982. Then Asia became the leader in the field, generating 15.1 TWh against European 13.6 TWh. In 1986, Europe moved to the third position, while Asia and Oceania and North America took over the leadership (their total share was 62.6% of total electric energy production using alternative energy sources). From 1989 to 2002, North America had the leading position in the industry. There was a rapid growth in the development of alternative energy in Europe in the late 1990s, and since 2003, the region once again ranks first in the world. Currently, alternative electric energy production in Europe is higher than in any other region in the world.

In the modern world, almost 50% of electric power is generated by wind power plants, slightly more than 30% – using biomass and waste, 9% – by solar and 6% – by geothermal plants, and less than 1% – by tidal and wave hydroelectric power stations.

3. Discussion.

The structure of alternative electric power underwent the most significant changes in the European region. The share of geothermal (from 19.1% in 1980 to 2.6% in 2014) and biomass (from 77.5 to 34.2%) power sources significantly decreased, at the same time the share of wind (operated since 1983; 46.6% in 2014) and solar (since 1984; 16.2%) resources increased. The majority of tidal and wave power stations are located in Western Europe, they have produced electric power at the level of 0.5 to 0.6 TWh per year for the last 30 years (but their share has gradually decreased from 5.8% to 0.3% over this period).

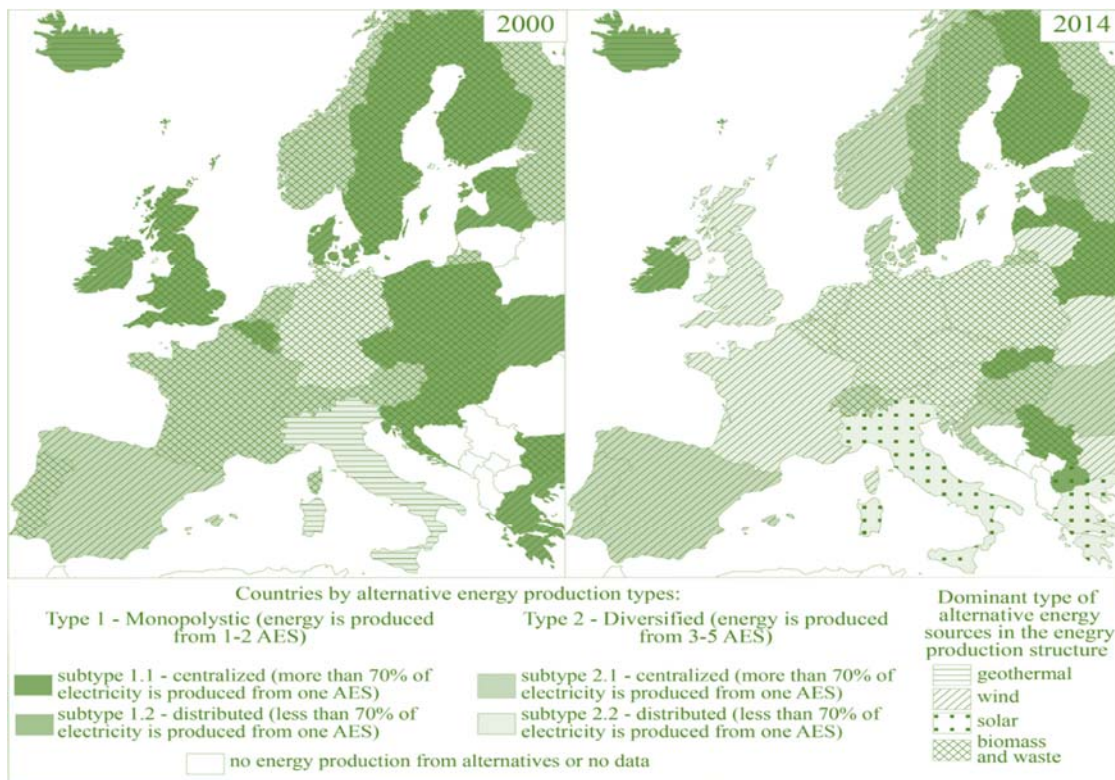
An increase in the share of electricity production using non-traditional sources is observed in all regions of Europe. The biggest share of alternative energy sources in electric balance in 2014 was in Southern Europe (18.1%), it was almost identical in Western (11.7%) and Northern Europe (12.5%), and only 2.1% of the alternative electric power was generated in the countries of Eastern Europe.

Currently, European countries are the world leaders in the development of alternative energy, especially Denmark (about 50%), Portugal (more than 30%), Iceland (about 30%), Spain (more than 20%), and Germany (more than 20%).

European countries can be divided into 4 types characterized with differences in alternative electric energy production dynamics trends. The first type is represented by the countries which do not produce alternative electric power (Albania, Moldova, Montenegro, etc.). The countries of the second type are characterized with an exponential growth in production (UK, Germany, France, etc.). In the countries of the third type a rapid growth has been noted (Belarus, Bulgaria, Poland, Romania, etc.) since 2005. A positive but unstable dynamics is typical of the countries belonging to the fourth type (Russia, Slovenia, Finland, etc.).

There were changes in the structure of alternative electricity production towards an increase in the use of wind power (the most intensive shift was in Italy, Portugal, and Ireland) and solar energy (in Germany, France, and Spain) from 1990 for 2014. There are territorial differences in the dynamics and structure (Figure 1) of alternative electric power industry development due to historical, natural, economic, environmental and innovative technology factors.

Figure 1. Typology of European countries by alternative electricity production



Source: set up by the authors

Typology of European Countries by Electric Power Industry Development Level in the 21st century. The characteristics of certain indicators and revealed territorial differentiation allow us to classify the countries by the electric power industry development level. Depending on the value of the integral index, the countries' rating was compiled, according to which 5 levels of the electric power industry development in Europe were identified:

- very high (VH) (with the index value from 3.51 and higher);
- high (H) (from 3.01 to 3.50);
- medium (M) (from 2.51 to 3.00);
- low (L) (from 2.01 to 2.50);
- very low (VL) (2.00 and less).

The results of the research show a positive dynamics of the electric power industry development in European countries over the period 1992 – 2014.

The tendency towards an increase in the integrated index value of certain countries and, consequently, their transition to the group of countries with a higher level of the electric power industry development is identified. This can be explained by an increase in the use of RES in the electricity generation structure, an increase in number of energy sources and a decrease in electricity consumption per GDP (by 45%) (Table 4).

Table 4. Integral index of electric power industry development level (*I_{EDL}*) by countries (1992 – 2014)

Country	1992	2000	2014	Country	1992	2000	2014
Albania	2.78	2.42	2.19	Latvia	2.00	2.28	2.69
Austria	3.53	3.78	3.81	Lithuania	2.14	2.31	2.56
Belarus	1.78	1.58	2.33	Luxembourg	2.39	2.89	3.06
Belgium	3.17	3.11	3.28	Macedonia	2.33	2.19	2.00
Bosnia and Herzegovina	2.11	2.33	2.83	Malta	2.28	2.36	2.67

Country	1992	2000	2014	Country	1992	2000	2014
Bulgaria	2.17	2.50	2.97	Moldova	1.56	1.25	2.33
Croatia	2.47	2.58	3.00	Montenegro	-	-	2.53
Cyprus	2.39	2.50	2.83	Netherlands	3.11	3.11	3.28
Czech Republic	-	2.86	3.50	Norway	3.97	3.97	3.81
Czechoslovakia	2.69	-	-	Poland	2.64	3.08	3.39
Denmark	2.58	3.17	3.42	Portugal	2.94	3.31	3.36
Estonia	1.89	2.33	2.81	Romania	2.69	2.89	3.58
Finland	3.50	3.33	3.42	Russia	3.58	3.36	3.75
France	3.72	4.19	4.08	Serbia	-	-	2.61
Germany	3.78	3.67	4.36	Serbia and Montenegro	2.36	2.56	-
Gibraltar	2.50	2.50	2.61	Slovakia	-	2.69	3.00
Greece	2.81	2.89	3.22	Slovenia	2.94	2.86	3.42
Hungary	2.33	2.42	2.50	Spain	3.28	3.36	3.86
Iceland	3.11	3.22	3.39	Sweden	3.61	3.64	3.94
Ireland	2.61	2.72	3.17	Switzerland	3.58	3.50	3.50
Italy	3.47	3.31	3.72	Ukraine	2.61	2.53	2.94
Kosovo	-	-	2.03	United Kingdom	3.42	3.50	3.89

Source: calculated by the authors

Over the period 1992 – 2014, the share of countries with a very high and high level of the electric power industry development increased, and at the same time the share of countries with a medium, low and very low level decreased. Now, the number of countries with a high and medium electric power industry development level prevail in Europe (Table 5, Figure 2).

Table 5. Structural results of typology of European countries by electric power industry development level (groups of countries) (1992 – 2014)

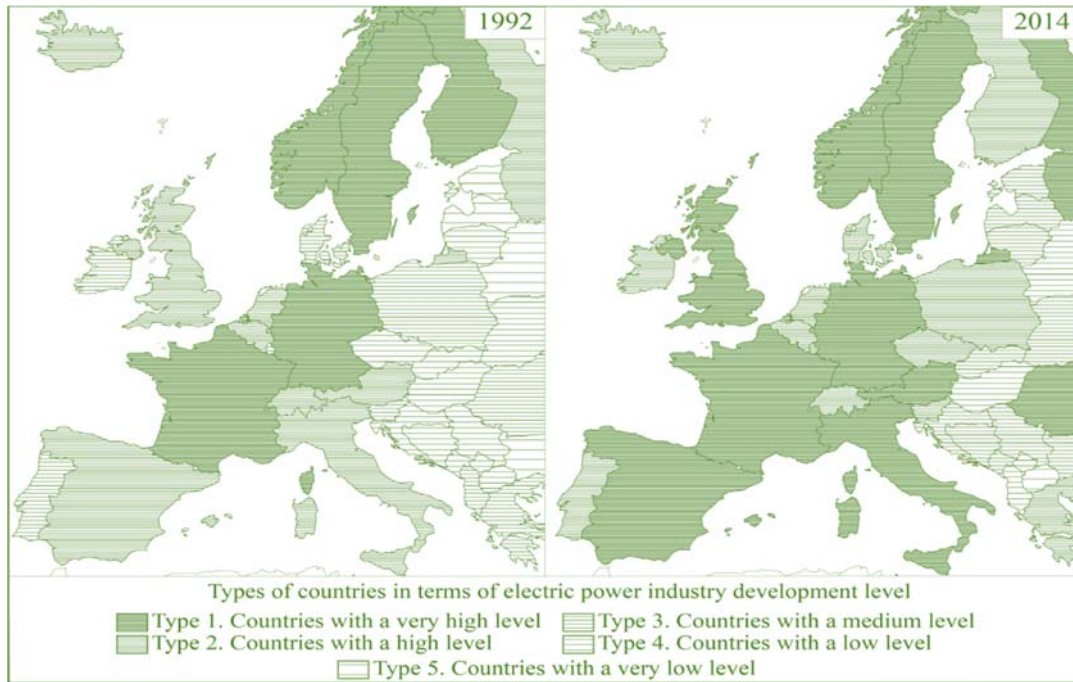
Types of countries by electric power industry development level	Years	Number of countries	Share, %	Average value of integral index
Type 1. Very high level	1992	7	12.8	3.68
	2014	10	23.8	3.90
Type 2. High level	1992	7	23.1	3.29
	2014	13	31.0	3.34
Type 3. Medium level	1992	10	23.1	2.70
	2014	13	31.0	2.80
Type 4. Low level	1992	11	28.2	2.30
	2014	5	11.9	2.30
Type 5. Very low level	1992	4	12.8	1.80
	2014	1	2.3	2.00

Source: calculated by the authors

Data for the year 2014 shows that countries of the first type are characterized with an average value of the integral index (3.9), the highest value of the electricity production volume, a high level of electricity independence, a high level of the electric power system capacity, a significant diversification of energy source types, and a high share of RES in the structure of electric power production. The average values of the studied indicators by the types are presented in Table 6.

The first type is represented by 10 European countries. These are: Germany, France, Sweden, United Kingdom, Spain, Austria, Norway, Russia, Italy, and Romania. As compared to 1992, the number of the first type countries increased. This type mostly includes developed countries, but recently Romania has joined them due to the growth in the RES share in its electricity generation structure.

Figure 2. Typology of European countries in terms of electric power industry development level



Source: set up by the authors

The second type has an average integral index value of 3.34. It differs from the first type by the decreasing values of such indicators as the volume of electricity production and capacity of the country's electric power system. This type is represented by the Czech Republic, Switzerland, Finland, Slovenia, Denmark, Iceland, Poland, Portugal, Belgium, Netherlands, Greece, Ireland, and Luxembourg.

The third type is characterized with an average value of the integral index of 2.80. A distinctive feature of this type is a higher rate of electric power independence, as compared to the countries of the first and second types, which is nearer or exceeds 100%, except for Lithuania (31.2%) and Latvia (72.9%). This type mainly includes the countries of the former socialist economic system (Croatia, Slovakia, Bulgaria, Ukraine, Bosnia and Herzegovina, Estonia, Latvia, Serbia, Lithuania, and Montenegro), as well as Cyprus, Malta and Gibraltar.

Table 6. Average indicators values in terms of electric power industry development level in European countries

Electric power industry development level	Indicators								
	1	2	3	4	5	6	7	8	9
1992									
Very high	324.3	112.2	74.9	11.2	5	46.2	314.6	9.9	6.2
High	122.7	100.4	31.3	8.6	5	25.2	273.7	7.4	6.9
Medium	61.2	121.9	16.1	8.2	4	19.5	240.2	3.4	12.3
Low	12.8	102.1	4.0	22.0	2	16.8	296.3	3.6	12.4
Very low	15.2	106.0	3.9	34.3	2	17.3	493.4	3.3	16.8
2000									
Very high	278.0	113.6	62.7	10.1	6	50.9	286.1	12.0	6.3
High	179.7	103.9	44.9	14.1	6	26.1	259.4	7.9	7.3
Medium	43.5	102.0	13.1	25.0	4	34.4	242.3	4.8	13.8
Low	10.9	117.3	3.5	13.1	2	22.4	234.0	3.0	17.5
Very low	14.9	90.4	4.4	33.6	2	3.7	536.9	2.2	20.9
2014									
Very high	339.0	111.3	102.0	10.2	6	45.7	204.1	8.0	7.5
High	55.3	97.1	16.5	32.1	5	39.0	269.8	10.4	6.4

Electric power industry development level	Indicators								
	1	2	3	4	5	6	7	8	9
Medium	25.4	105.2	8.2	31.1	4	29.3	236.5	4.3	10.4
Low	14.9	97.0	4.4	36.3	4	24.6	216.5	2.5	24.9
Very low	5.0	72.7	2.0	44.4	2	23.7	264.8	3.3	21.2

1 - electricity generation, TWh; 2 - electric power independence, %; 3 – electric power system capacity, GW; 4 - import share in electricity consumption, %; 5 - number of electrical energy sources, unit; 6 - share of electricity generation from RES, %; 7 - electricity consumption per GDP, kWh/1000 USD; 8 - electricity consumption per capita, MWh/capita; 9 - electric power transmission and distribution losses, %

Source: calculated by the authors

The fourth type is characterized with an average value of the integrated index of 2.30, as well as significantly lower values of indicators (electricity generation volume, electric energy system capacity, RES share, electricity consumption per capita) as compared to previous types. Over the studied period, the number of countries belonged to the fourth type greatly decreased. In 1992, 11 countries had a low level of electric power development. Nowadays, only 5 countries represent the fourth type. These are: Hungary, Moldova, Belarus, Albania, and Kosovo. They have the biggest losses in electrical networks.

The fifth type is characterized with an average value of the integral index of 2.00 and lower values of most of the studied indicators (volume of electricity production, capacity of the country's electric power system, number of electric power sources, share of electricity produced from RES, etc.). It should be noted that the number of countries of this type significantly reduced over 1992 – 2014, and currently the 5th type is represented only by Macedonia.

Conclusion

European countries are characterized with a diversification of energy sources, intensive involvement of RES in the electric power balance, high sectoral and intrasectoral territorial concentration of electrical energy production. In the modern structure of electricity production from alternative energy resources in Europe, more than 45% of electricity is produced from wind sources, about 35% – from biomass and waste, more than 15% – from solar ones and about 3% – from geothermal sources. At the same time, during the period 1992 – 2014, the main sectoral shifts are as follows: an increase in the share of wind and solar energy and a decrease in the share of geothermal and biomass sources. There has been an increase in the absolute values of electric power generation from AES in all regions of Europe, while the largest share of AES in the electric balance has been observed in the countries of Southern Europe. The countries of Eastern Europe have the smallest share of AES.

There is a tendency towards energy resources diversification in Europe, but countries differ in terms of electricity production structure. So, three types of countries can be distinguished: with monospecialized, combined and diversified structure of electric power industry. Currently the countries with diversified structure dominate.

Calculations and analysis of the electric power industry development trends made it possible to present the typology of the countries and identify differences between them in terms of electricity production and consumption, electricity balance, sectoral structure and alternative energy development rate. Over more than 20 years, significant regional transformations have occurred: the number of countries with a very high, high and medium level of the electric power industry development has increased and that of countries with a low and very low level decreased.

The regionalization of the European electric power industry formed by the beginning of the 21st century, considering a high level of this industry development, caused a merger of the electric power markets of European countries in the Single Regional Market. According to the principles of sustainable development of Rio+20, priorities of “green economy”, a tendency towards global decarbonization of the world economy in the 21st century and intensive development of alternative energy in Europe, the key direction of the electric power industry efficiency enhancement will be further development of innovative technologies and the wider use of renewables.

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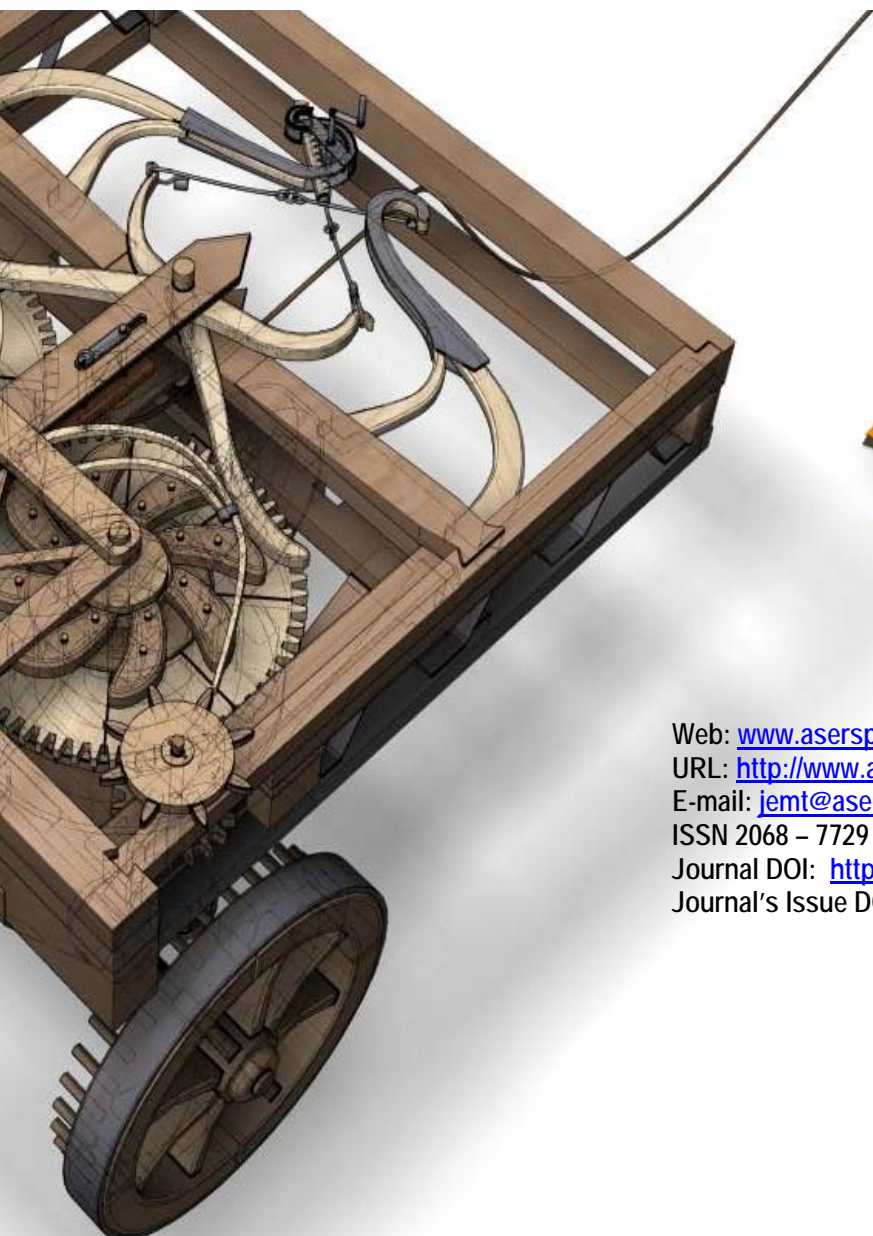
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