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ENERGY INTENSITY OF ECONOMIES IN THE EUROPEAN UNION AND THE WORLD

Słowa kluczowe: energy, energy intensity, economy, economic growth, European Union

ABSTRACT. The technological nature of human existence depends on the energy that has become a condition for the existence of every civilization and the driving force of every action. This confirms the modern dependence of humanity on energy, which determines economic growth and standard of living. It can also be a source of international conflicts. One of the main problems is the limited nature of its sources, especially non-renewable ones. Today, energy is a key factor in the development of the World and countries, characterized by different effectiveness of its use. Therefore, the main objective of the article was to assess the energy intensity of EU and world economies. World leaders in this field and countries with the highest energy consumption per unit of GDP were presented. The structure of energy sources in EU countries was also analyzed. It was found that 4 countries with the highest energy consumption account for 51% of global consumption, which indicates a very high level of concentration.

INTRODUCTION

Energy resources are an element of natural resources intensively exploited in the modern world. Civilization and economic development are causing a growing demand for energy, which is a multidimensional concept [Gradziuk 2015]. They can be considered in various aspects:

– economical – energy is a good or a set of goods that are traded on global markets,
– ecological – energy sources are classified as clean or polluting the environment, and the main goal is sustainable development,
– social – access to energy is a basic social value resulting from the need to meet living needs, which forces fair distribution among consumers,
– geopolitical – energy resources and the geographical location of resources (mainly fossil fuels) shape inter-state relations and the country's energy security.

Energy resources have an impact on economic processes in the modern world, their role and importance for the economy are decisive. Every type of human economic activity requires the use of energy. Agriculture, industry, the production of goods or provision of services do not function without the smallest amount of energy, in particular from crude

oil, natural gas and coal. A land without hydrocarbons would face disaster. The challenge for humanity is, therefore, proper resource management, which is exhaustible and unevenly distributed around the World. Several countries have over 80% of the World's reserves (in the case of coal, 10 countries with the largest deposits have 93% of global reserves). This arrangement of energy potential causes other countries and societies to depend on resource monopolists. This is a problem as modern civilization is more than ever a "slave of energy", and thus countries that have raw materials.

Economic growth, its origin and size – is the main focus of modern economic research [Kuznets 1971, Rostow 1971, Barro 1997, Galor 2005]. The relationship between energy consumption and the growth of gross domestic product met with great interest among scientists [Stern 2004, 2010, WEF 2012, Ayres 2014]. Strong long-term correlations between economic growth and energy consumption have been observed at both global and national levels.

Between 1900 and 2000, primary energy consumption increased almost eightfold, from 44 to 382 EJ[1], and Gross World Product increased more than 18 times, from around USD 2 trillion to nearly USD 37 trillion at constant 1990 prices [Smil 2010, Maddison Project 2013], which means flexibility less than 0.5. For example, in the 20th century Japanese GDP increased 52-fold and total energy consumption 50-fold (flexibility very close to 1.0), while the coefficients for the United States were almost 10-fold and 25-fold, respectively (flexibility less than 0.4), and for China almost 13-fold and 20-fold (flexibility 0.6). For a country to become rich, it is necessary to significantly increase absolute energy consumption. The relative increase in energy consumption, measured per unit of GDP or per capita, however, varied greatly. Examples were Italy and South Korea. In 2014, both countries had a very similar GDP per capita level (according to purchasing power parity) of around USD 35,000, however, energy consumption per capita in South Korea was almost 90% higher than in Italy. Germany and Japan had almost identical annual energy consumption of around 170 GJ/capita, but in 2014 Germany's GDP was almost 25% higher [IMF 2015, USEIA 2015].

From the analysis of long-term trends in energy consumption per capita and economic growth, it can be concluded that high levels of economic growth can be achieved with less energy consumption per capita. In the United States, the continuous, albeit slow, population growth has brought further increases in absolute fuel and electricity consumption, but average primary energy consumption per capita has not changed significantly over three decades. During this time, real GDP per capita increased by almost 57%, from USD 32,288 in 1985 to USD 50,456 in 2014 [FRED 2015]. Similarly, in both France and Japan, primary energy consumption per capita stabilized in the mid-1990s, but in the next two decades, the average GDP per capita increased by around 20 and 10%, respectively.

[1] Exajoule – a unit of measure for energy consumption (1,018 Joules).

RESEARCH MATERIAL AND METHODS

The main purpose of the article was to assess the energy consumption of EU countries. For this purpose, the Global Economy Energy Consumption Index (*GEECI*) was proposed and used, calculated according to the formula:

$$GEECI = \frac{E}{GDP}$$

where: E – energy consumption in the country (kgoe), GDP – gross domestic product of the country (USD/EUR).

The proposed method is a simple measure in which energy expenditure is related to the monetary market value of all final goods and services produced in the countries studied.

The Gini coefficient was used to determine the level of energy consumption concentration in the EU. It is closely related to the Lorenz curve (hence its other terminology, "the Lorenz concentration coefficient"). This is a measure of inequality, which is why it has many formal representations. One of them is presented below:

$$G = \frac{1}{2\mu n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} \left| x_i - x_j \right|$$

where: n – average energy consumption, μ – sample size.

The Gini coefficient takes the value 0 for egalitarian distribution and 1 for extreme inequality. From the formula given, it can be interpreted as the ratio of half the absolute difference in consumption between all countries to average consumption. This factor meets the Pigou-Dalton transfer principle (when transferring consumption from countries with higher consumption to those with lower consumption it changes), symmetry, homogeneity and replication. However, it does not meet the postulate of decomposition.

The Lorenz curve shows the cumulative percentage of energy consumption attributable to subsequent countries, ranging from those with the lowest consumption to those with the highest. In the theoretical case, when the consumption of all countries is equal, the Lorenz curve takes the form of a straight line inclined at an angle of 45 degrees (absolute equality curve). However, this situation does not occur. The greater the variation in inequality in wear, the more the real curve deviates from the absolute equality curve. The quantitative measure of this inequality is the Gini coefficient, which is twice the area between the real curve and the absolute equality curve. It can take values from 0 – absolute equal consumption to 1 – all consumption concentrated in one country.

During the research, various types of reports and databases were used, including Eurostat.

RESEARCH RESULTS

The consequence of global economic growth is constantly increasing absolute energy consumption. In 2016, about 240% more energy was used than half a century ago. Considering the decades, the largest increase (almost 54%) took place between 1966 and 1976. The smallest increase in consumption occurred in the last analyzed decade. In 2016, 17.8% more primary energy was used than in 2006. The only year in the last decade in which there was a decrease in consumption compared to the previous year was 2009. This was mainly due to the global financial crisis that began in 2007.

The decrease in energy consumption also took place in 1980-1982. This was a result of the second oil crisis (the result of the Iranian revolution). This crisis took place in 1979-1982.

Energy consumption in the 21st century is increasingly dominated by Pacific Asia, which, in 2016, was responsible for 42% of global primary energy consumption. It is noteworthy that 50 years earlier this region was 3rd in the World with a share of consumption of only 12%. In 1966-2016, primary energy consumption in Pacific Asia increased more than 11 times. The current position of the region is mainly due to China's energy consumption, which, in 2016, consumed more primary energy (3,053.0 Mtoe) than any of the regions. Another trend was observed in North America, Europe and Eurasia, where consumption remains at a similar level or is decreasing. It is a derivative of slower economic growth as well as energy and environmental policy focused on improving efficiency and reducing greenhouse gas emissions. During the period under consideration, energy consumption in the Middle East increased almost 17 times.

China is the world leader in terms of primary energy consumption, accounting for 23% of global consumption in 2016. The countries with the highest consumption are economic powers, inhabited by a huge number of people. Currently, almost 51% of the World's energy is consumed by only 4 countries (China, the United States, India and Russia).

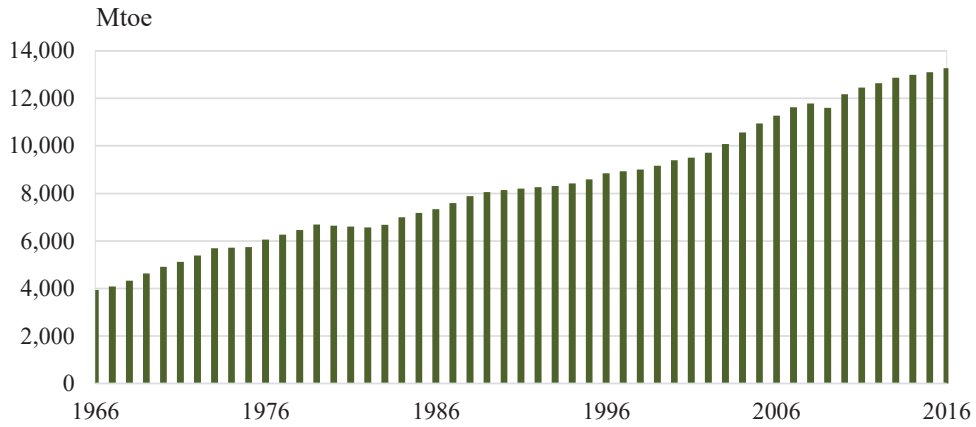

Figure 1. Total primary energy consumption in the world in 1966-2016
Source: [BP 2017]

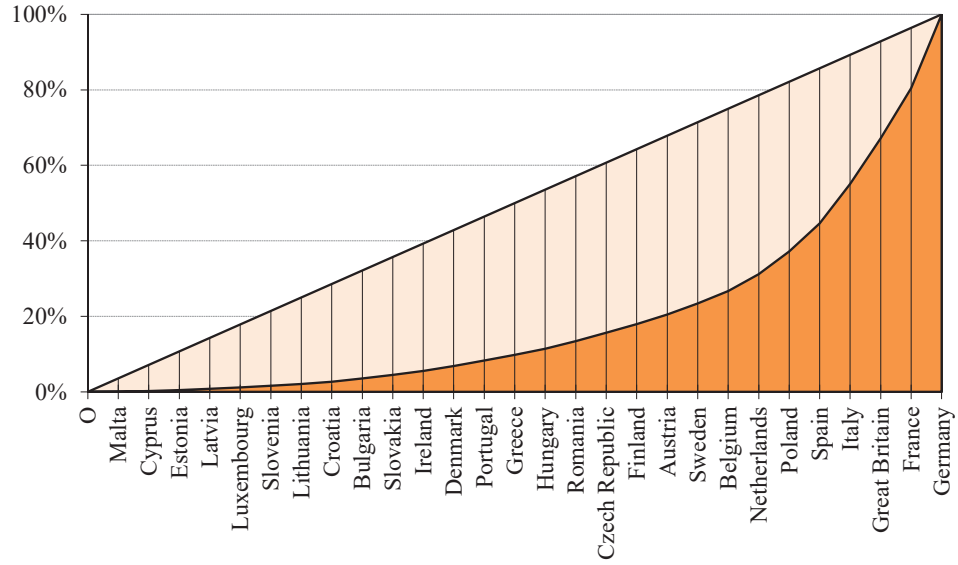

Figure 2. The concentration of final energy consumption in 2016
Source: own study based on [Eurostat 2018a]

Primary energy consumption in the EU is characterized by a downward trend, which is mainly due to the adopted goals of reducing energy consumption and protecting the climate.

In 2016, Germany, France, Great Britain, Italy, Spain and Poland consumed the most energy in the EU (65% of energy in the European Union), as illustrated by the Lorenz curve (Figure 2). This was also confirmed by the Gini index, which in 2016 was 0.613. It is worth noting that, in 2004, the concentration of energy consumption in the EU was at a similar level – the Gini index was then 0.616.

There was a clear differentiation of energy sources consumed in individual EU countries. The share of crude oil in the total structure of primary energy consumption was highest in Belgium (51.4%) and the Netherlands (47.2%). In the case of natural gas, Italy was the leader (38.3%), which was slightly ahead of Great Britain (36.7%) and the Netherlands (35.7%). Poland (50.4%) was the country with the largest share of coal consumption in the total structure. Nuclear energy was a very important source of energy in France (30%). Sweden was close to this level (27.2%). Poland and Italy did not use nuclear energy in 2016. Renewable energy was the most important in Sweden (38.7%), and the smallest in the Netherlands (3.7%), Belgium (5.2%), Poland (5.3%) and the Czech Republic (5.3%).

The structure of primary energy consumption in the EU varies considerably from one country to another. On average, across the EU, the most energy in 2016 was used in transport - 33.1% of total consumption. The next places were followed by the household sector (25.4%), industry (25.3%), services (13.5%) and agriculture (2.1%). In the case of transport, the largest share in energy consumption was recorded in Luxembourg, Malta and Cyprus. Households dominated the energy consumption of Croatia, Hungary and Romania. The industry had the largest share in Finland, Slovakia and Sweden. The service sector

Table 1. List of countries with the lowest and highest energy intensity of gross value added in 2016

No.	Country	Energy intensity of GDP [kgoe/USD 1,000]
	Countries with the lowest energy intensity	
1.	Switzerland	40
2.	Ireland	52
3.	Denmark	56
4.	Great Britain	72
5.	Italy	82
	Countries with the highest energy intensity	
1.	The Ukraine	933
2.	Trinidad and Tobago	922
3.	Turkmenistan	919
4.	Uzbekistan	784
5.	Iran	688

Source: [BP 2017, World Bank 2017]

had the largest share in the consumption structure in Malta, Estonia and Latvia. The greatest importance of agriculture in the structure of energy consumption was recorded in the Netherlands (7.4%), Poland (5.3%) and Estonia (4.8%), while the smallest in Luxembourg (0.6%), Great Britain (0.8 %) and Malta (0.9%). The list does not include Germany, as there was a lack of data on energy consumption in agriculture.

Households had the largest share in final energy consumption in Poland, in 2016 - 30.3% (more than the EU average). Transport had the second largest share (27.7%), while the industry had the third largest (24.17%). In the case of agriculture, Poland is characterized by more than twice a higher share of agriculture in the structure of energy consumption than the average for all EU countries.

One of the measures used in research on energy use is energy intensity. In macro terms, most often it is energy consumption expressed in units of energy consumption per GDP unit (Table 1). Among the countries with the lowest energy intensity of the economy, there were 7 European and 3 Asian countries. The leader was Switzerland, which needed 40 kgoe to generate USD 1,000 of GDP. Ireland and Denmark had an energy intensity index below 60.

The country with the highest energy intensity of GDP among the surveyed group of countries was the Ukraine, which consumed over 23 times more energy than Switzerland to produce the same GDP value. The world's largest economies are very diverse in terms of energy consumption. The list includes both countries that need less than 100 kgoe to generate USD 1,000 of GDP (Japan, Germany, Great Britain, France and Italy) and those whose energy consumption index (GEECI) is about 300 (China and India). This is primarily due to the level of economic development of countries.

EU countries are among the leaders in global energy consumption. In 2004-2016, the indicator decreased from 151.5 kgoe/EUR 1,000 in 2004 to 118.6 kgoe/EUR 1,000 in 2016 (Figure 3). The Bulgarian economy was the most energy-intensive in the entire EU. In 2016, it needed 422.6 kgoe to generate EUR 1,000 of GDP (630.6 kgoe/EUR 1,000 in 2004). This indicator was almost four times higher than the average value for all EU countries and more than 7 times higher than in Ireland, which was the leader in this ranking. Poland, despite significant improvement, was among the most energy-intensive countries of the European Union. The negative phenomenon in the Polish case was a far too slow pace of improvement in energy intensity.

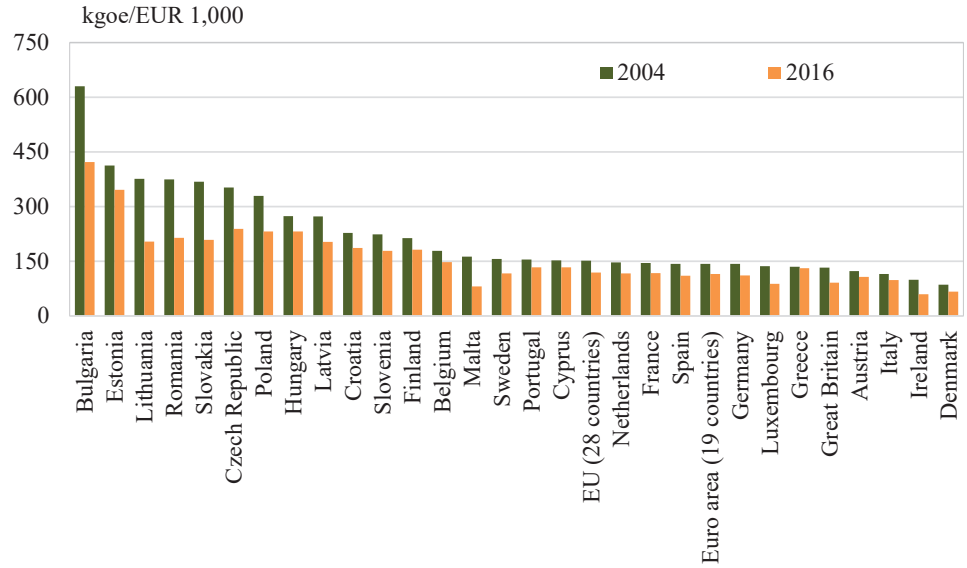

Figure 3. Energy intensity of the economy in EU countries in 2004-2016
Source: own study based on [Eurostat 2018b]

Compared to 2004, the largest improvement in energy intensity of the economy (over 40%) took place in Malta, Lithuania, Slovakia, Romania and Ireland. The average change for all EU countries was almost 28%. Poland was in a group of 15 countries whose change in the index was greater than the EU average and was around 30%. The lowest change was recorded in Greece – 3.18%.

CONCLUSIONS

In the years 1966-2016 (except for 1981-1982 and 2009), there was a continuous increase in energy consumption in the World. Over the entire period, this increase was 240%.

The share of individual regions of the World in energy consumption has changed. Pacific Asia increased its share, accounting for 42% of global energy consumption in 2016 compared to 12% in 1966. Such a high position of Asia was mainly due to high energy consumption by China, which, in 2016, had a share of 23% of global primary energy consumption in the World. Another trend was observed in North America, Europe and Eurasia, where consumption remains at a similar level or is decreasing, which is a consequence of slower economic growth and pro-environmental activities.

A high level of concentration of energy consumption in the World was found - four largest consumers (China, USA, India and Russia) accounted for 51% of consumption. A similar trend has also taken place in the EU. Six countries (Germany, France, Great Britain, Italy, Spain and Poland) used 65% of energy in the European Union in 2016. In the years 2004-2016, the level of concentration remained at a similar level.

Differences in the structure of consumed energy sources were found in EU countries. Crude oil dominated in Belgium and the Netherlands, accounting for about 50% of energy consumed. Natural gas was the main source in Italy and Great Britain (about 40%). Hard coal was the most important source in Poland (over 50%). Nuclear energy was key in France (30%), while renewable energy was the most important source in Sweden (40%).

The lowest energy intensity of the economy in the World was achieved in Switzerland. In 2016, Ireland, Denmark and Italy needed the least energy to generate a unit of GDP in the European Union. The worst in this ranking, Bulgaria used 4 times more energy to produce EUR 1,000 of GDP than the EU average and 7 times more than Ireland. In 2004-2016, the largest improvement in energy intensity (above 40%) was recorded in Malta, Lithuania, Slovakia, Romania and Ireland. On average, the EU improved by 28%.

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ENERGOCHŁONNOŚĆ GOSPODARKI W KRAJACH UNII EEUROPEJSKIEJ I ŚWIATA

Słowa kluczowe: energia, energochłonność, gospodarka, wzrost gospodarczy, Unia Europejska

ABSTRAKT

Celem głównym artykułu jest ocena energochłonności gospodarek krajów Unii Europejskiej i świata. Technologiczny charakter ludzkiej egzystencji jest uzależniony od energii, która stała się warunkiem istnienia każdej cywilizacji i siłą sprawczą każdego działania. Potwierdza to współczesne uzależnienie ludzkości od energii, która decyduje o wzroście gospodarczym, standardzie życia, a także może być źródłem międzynarodowych konfliktów. Jednym z głównych problemów jest ograniczoność jej źródeł, w szczególności tych nieodnawialnych. Energia to współcześnie kluczowy czynnik rozwoju świata i poszczególnych państw, charakteryzujących się różną efektywnością jej wykorzystania. W artykule przedstawiono światowych liderów w tym zakresie i kraje o najwyższym zużyciu energii w przeliczeniu na jednostkę PKB. Przeanalizowano ponadto strukturę źródeł energii w poszczególnych krajach UE. Stwierdzono m.in., że 4 kraje o największym zużyciu energii, odpowiadają za 51% światowego zużycia, co świadczy o bardzo wysokim poziomie koncentracji.

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