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ECONOMIC AND ENERGY EFFICIENCY OF AGRICULTURE IN POLAND COMPARED TO OTHER EUROPEAN UNION COUNTRIES

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ABSTRACT

Modern agriculture is dependent on external energy sources. Non-renewable energy sources play a dominant role, which contributes to greenhouse gas emissions and, as a consequence, to environmental degradation. Therefore, it becomes obvious to strive to improve energy efficiency and change the structure of its sources. One of the main research goals was to determine the economic and energy efficiency of agriculture in EU countries and assess its energy consumption by analysing energy consumption per employee or 1 ha of utilized agricultural area. The work analyses changes in energy consumption in agriculture of the European Union and its members. Eurostat data was used for the analysis.

Key words: economy, energy, efficiency, agriculture, EU
JEL codes: O13, Q1, Q4

INTRODUCTION

One of the resources conditioning the functioning and development of humanity are limited natural resources. The problem of management and scarcity of natural resources concerns not only modern society. Although this problem has not always been dealt with in the theoretical sphere, it has practically always been present, but to varying degrees. People have always managed environmental resources, but at first, they did not do it consciously. This led to over-exploitation and limited resources, which became a barrier to the further development of the community. In the period before globalization, such phenomena were of a regional and incidental nature [Schefold 1985].

The economic theory of natural resources management deals primarily with the study of the optimal distribution during the exploitation of renewable or non-renewable natural resources [Fiedor 2002]. This refers to their limitations in dynamic terms.

In the case of resources, the most important is the rationality of management, which is one of the key concepts in economics [Bochenek 2008]. The purpose of allocating limited resources is to maximize benefits.

According to Kulawik [2008], rationality consists of the optimal selection of the proportion of individual expenditures taking into account the limited resources. It involves, among other things, the difficulty of obtaining some raw material because it is a rare good or because its limitedness is associated with high costs [Kulawik 2008]. Rationality takes on special significance

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in the 21st century in the context of natural resources, which, apart from capital and human resources, have become the basis of management [Piasecki 2011].

An example of a natural and rare resource is the energy obtained from both renewable and non-renewable sources. In classical economics, energy was treated as a free good [Czaja 2002], but this understanding of energy does not currently meet the needs of economic practice. As a result of the development of civilization and the huge increase in material production, energy has lost the nature of a free good and, like the vast majority of natural resources, has become an economic good, which because of its limited nature is an object of management.

The increasing dependence on energy imports and the limited energy resources, as well as the need to slow down negative climate change, contribute to the fact that the issues of energy efficiency, in particular the search for solutions enabling energy savings, creates an obligation for theoretical and experimental research [Szczepaniak 2014].

An example of research on energy efficiency in individual sectors of a given country is the study of de Castro Camioto et al. [2014]. The authors assessed the effectiveness of industrial sectors in Brazil in 1996––2009 in the field of energy consumption using the data envelopment analysis (DEA) method. The input variables were the ability to reduce energy consumption and carbon dioxide emissions from fossil fuels, while the output variables were the GDP growth in the employment and personal expense sectors. It was found that the most effective sector in Brazil under the adopted assumptions was the textile industry. The next places were the following sectors: food and drink, chemical, mining, paper and cellulose, non-metallic and metallurgical.

When it comes to the energy efficiency of agriculture, it is worth paying attention to the research of Alluvion et al. [2011]. These researchers presented energy efficiency in three crop systems: low input, integrated, and compliant with EU regulations and traditional conventional. It was found that compared to the last system, in the first two, the energy efficiency increased by 32.7% and 31.4%, respectively.

Noteworthy is the study by Uzal [2013], which compared the energy efficiency of milk production in two farms: in the first, dairy cattle were reared in a free-standing system, in the second in a free-range system. It was found that in both cases the largest percentage of energy expenditure came from feed and electricity consumed. Total energy consumption per hectare was lower on farms using a free-standing system. The research results of Gronroos et al. [2006] are also interesting. Energy consumption in traditional and organic milk and rye bread production in Finland was examined. The basic energy consumption in traditional milk production was 6.4 GJ per 1,000 l of milk and 4.4 GJ in organic production. For rye bread production, it was 15.3 and 13.3 GJ per 1,000 kg of rye bread, respectively. Meul et al. [2007] examined the energy efficiency of farms specialized in milk, pig and plant production. These farms were located in the Flemish region in Belgium. It was found that the most energy-efficient farms specialized in milk and pig production were intensive production farms that combined high productivity with low energy inputs. In the case of plant-based farms, unambiguous relationships could not be indicated, as energy efficiency depended strictly on crop rotation.

In the study of Mousavi-Avval et al. [2011], the results of research on the energy efficiency of rapeseed production and analysis of the costs of this production depending on the production volume in Iran were presented. It was found that along with the increase in farm size, energy expenditure per hectare increases. At the same time, the highest yields were recorded in medium-sized farms, which were additionally characterized by the highest energy efficiency and the best ratio of revenues to costs.

The DEA method is a popular tool used for research on the energy efficiency of agriculture. Firoozi et al. [2014] used it to evaluate and optimize energy consumption in growing cucumbers under shelter in Iran. It was found that by improving inefficient elements, it is possible to save over 18% of energy expenditure. A good example of the use of DEA is also the research of Chauhan et al. [2006], where a method was used to determine the efficiency in terms of energy consumption in rice production in India. During the research, a sample of farmers using energy efficiently and inefficiently was determined. Inefficient energy applications were identified and, based on solutions used in the most effective crops, energy-saving solutions were developed. It was finally found that it is possible to save around 12% of the energy used to produce rice.

MATERIAL AND METHODS

The research aimed to recognize the efficiency of energy use in agriculture in individual EU countries and changes in the share of agriculture in total energy consumption in these countries. Another important research task was to assess the efficiency of energy used in agriculture in EU countries. To this end, two original economic and energy efficiency indicators (*GIEEE*, *GIREEE*) were used. The limitation of the study was to consider only one input and one output, which does not allow a comprehensive assessment of the effectiveness tested. Calculations and analyses were made based on Eurostat data from 2016. Due to the lack of data, Germany was not included in the study.

Global indicator of economic and energy efficiency (*GIEEE*)[1] of agriculture was calculated according to the formula:

$$GIEEE = \frac{GVA}{E}$$

where:
GVA – gross value added of agriculture (million EUR),
E – energy consumption in agriculture (thousand toe).

The indicator was used to assess the economic and energy efficiency of agriculture in EU countries.

Global index of relative economic and energy efficiency (*GIREEE*) of the economy (agriculture) sector against the country's economy as a whole:

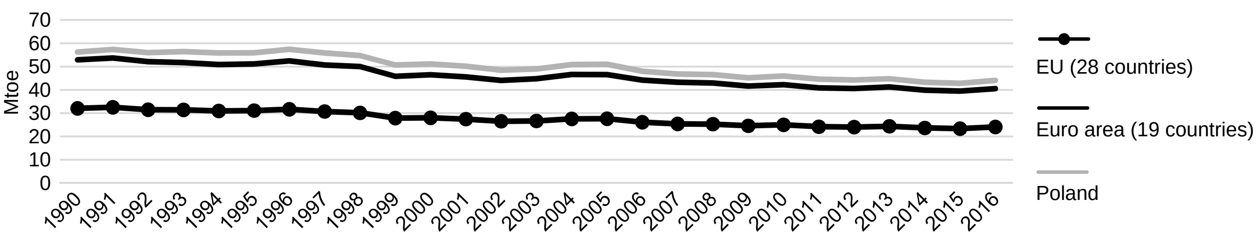
$$GIREEE = \frac{\frac{GVAr}{Er}}{\frac{GVA}{E}}$$

where:
GVAr – gross value added of agriculture in a given country (million EUR),
GVA – gross value added of the country (million EUR),
Er – energy consumption in the agriculture of a given country (thousand toe),
E – energy consumption in the country (thousand toe).

The indicator of relative economic and energy efficiency was used to assess the effectiveness of agriculture against the economy of a given EU country. An index that is above unity means that the economic and energy efficiency of agriculture is greater than the overall economy.

RESULTS AND DISCUSSION

As part of the study, it was found that the final energy consumption in EU agriculture was characterized by a decreasing trend – from 1995 to 2016 consumption on average across the European Union decreased by 27%, in the euro area by 22.7%, while in Poland by 2.6% (Fig. 1). In 5 out of 28 countries, an increase in final energy consumption in agriculture was noted: Cyprus (increase by 806.5%), Luxembourg (by 110.5%), Belgium (by 47.9%), Spain (by 34.8%) and France (by 18.3%). The greatest reductions were made in Lithuania (reduction of consumption by 87.7%), Estonia (by 81.4%), Slovakia (by 78.7%), Bulgaria (by 76.5%) and Greece (by 75%).



Data for Germany are incomplete since 1999. Consumption for Slovenia (until 1997) and Malta (until 2008) is not included.

Fig. 1. Final energy consumption in agriculture in Poland, Euro area countries and EU-28 in 1990–2016
Source: Authors' own study based on [Eurostat 2018a].

[1] The indicator can be used for direct comparisons of countries, branches of economy, enterprises.

In 1995–2016, the share of agriculture in total final energy consumption on average in the EU fell by 0.7 p.p., while in the euro area countries by 0.6 p.p. (to the greatest extent in Greece – by 4.8 p.p.). The reverse trend was observed in 5 countries: Cyprus, Estonia, Latvia, France and Luxembourg. By far the largest share of agriculture in total energy consumption in the EU took place in the Netherlands and Poland (Table 1).

The final energy consumption in EU agriculture per employee in 2016 amounted to an average of 2,306.33 kgoe[2] and was higher by over 273 kgoe than in 2004. This is mainly due to the decreasing number of people employed in agriculture. Three countries were leaders in this respect: the Netherlands, Belgium and Denmark, i.e. countries characterized by relatively low employment and intensive agriculture, which determines the increased demand for energy. On the other side of the list, there are countries where the share of those employed in agriculture is one of the largest in the EU, there is a small concentration of production, and agriculture is often extensive – Romania (223 kgoe), Bulgaria (296 kgoe) and Greece (586 kgoe). In 2004–2016, energy consumption per employee dropped most in Greece (71.3%), Sweden (57.6%) and Ireland (33.6%) – Figure 2.

Another important indicator is the final energy consumption in agriculture per 1 ha of UAA (Fig. 3). In 2016, the leader was the Netherlands (2,052.93 kgoe per 1 ha), consuming nearly 4 times more energy per 1 ha of UAA than the second in ranking Belgium and over 15 times more than the average in all EU countries. This is due to very intensive agriculture and a high share of greenhouse production requiring high energy expenditure. The lowest final energy consumption per 1 ha of UAA was observed in Romania (33.5 kgoe per 1 ha), Lithuania (35.3 kgoe per 1 ha) and Bulgaria (36.8 kgoe per 1 ha). The largest improvements occurred in Greece (83.2%), Sweden (53.5%) and Ireland (38.2%). In Poland, both indicators increased in the period considered.

A simple indicator was proposed to assess the economic and energy efficiency of agriculture in individual EU countries, in which the gross value added of agriculture was divided by the energy consumption in

Table 1. Share of agriculture in total final energy consumption in 1995, 2005 and 2016

Country/group of countries	Share of agriculture in total final energy consumption (%)		
	1995	2005	2016
EU (28 countries)	2.9	2.3	2.2
Euro area (19 countries)	2.7	2.2	2,1
Austria	2.5	2.0	2.0
Belgium	3.2	2.2	2.0
Bulgaria	3.4	3.0	2.0
Croatia	3.8	2.9	3.1
Cyprus	0.4	2.1	2.5
Czech Republic	4.7	2.1	2.5
Denmark	5.0	4.4	4.5
Estonia	3.3	3.6	4.8
Finland	3.4	2.8	2.8
France	2.5	2.7	2.9
Greece	6.4	5.5	1.6
Hungary	4.1	3.1	3.3
Ireland	4.3	2.7	2.0
Italy	2.6	2.2	2,3
Latvia	3.2	3.1	4.1
Lithuania	4.4	2.2	2.0
Luxembourg	0.4	0.5	0.6
Malta	x	x	0.9
Poland	7.6	7.6	5.3
Portugal	3.5	2.7	2.2
Romania	3.7	0.9	2.1
Slovakia	2.7	1.4	1.5
Slovenia	x	1.5	1.6
Spain	3.4	3.2	2.8
Sweden	2.2	2.2	1.1
Great Britain	0.9	0.6	0.8
Netherlands	8.3	7.2	7.4

x – no data or incomplete data.

Source: Authors' own study based on [Eurostat 2018b].

[2] Kilogram of oil equivalent (kgoe) is a unit of conventional fuel. According to the definition contained in the Act of 15 April 2011 on energy efficiency, kgoe is equivalent to 1 kg of crude oil with a calorific value of 41.868 kJ.

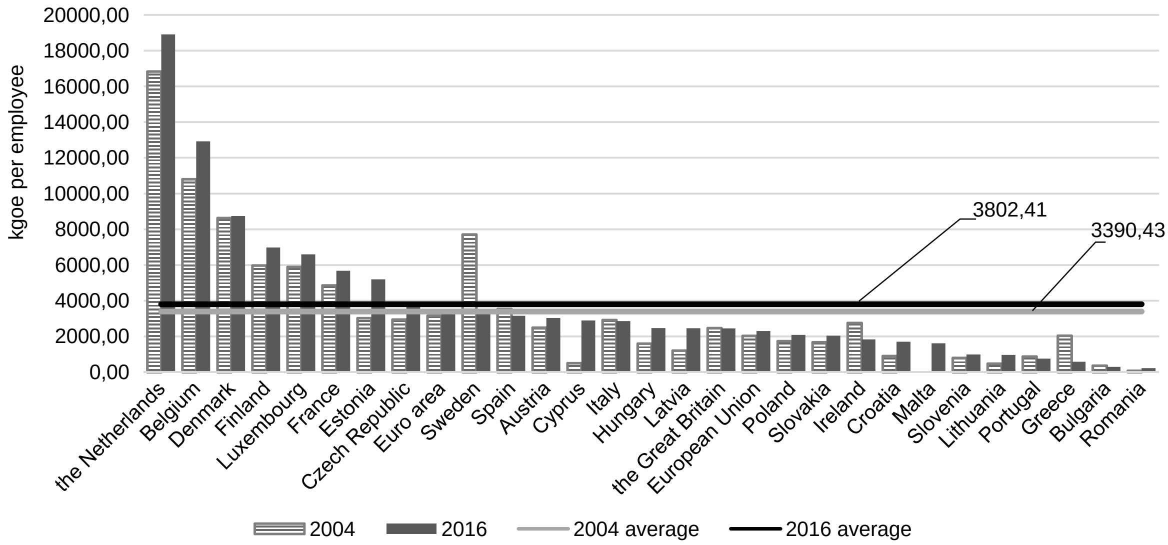


Fig. 2. Final energy consumption in agriculture/forestry in 2006 and 2016

Source: Authors' own study based on [Eurostat 2018c].

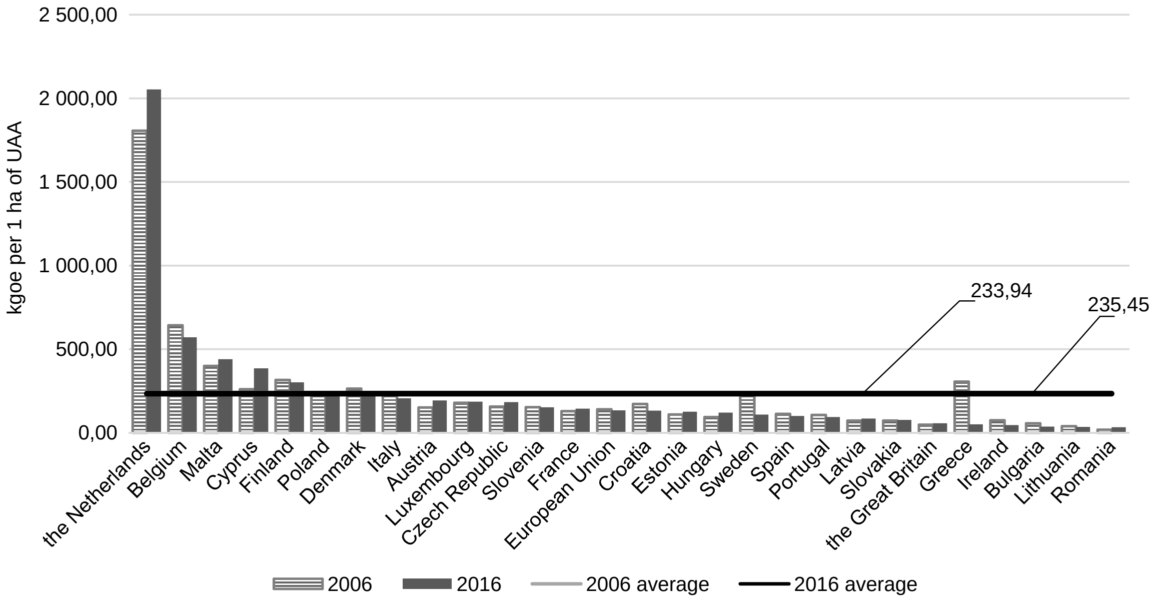


Fig. 3. Final energy consumption in agriculture/forestry in 2006 and 2016

Source: Authors' own study based on [Eurostat 2018d].

this sector (Table 2). In 2016, the highest values of the indicator were observed in Greece and Slovakia, with the lowest in Poland and Estonia. In the years 2004––2016, the value of the indicator increased in 21 EU countries, which is a positive phenomenon indicating increasing energy productivity. Interesting was the decline in the indicator in Romania. The reasons can be seen in the progressing intensification and mechanization of agriculture in this country and as a result of increased energy expenditure.

Table 2. Economic and energy efficiency of agriculture in EU countries in 2004–2016

Country/ /group of countries	Gross value added in agriculture – current prices (million EUR)		Final energy consumption in agriculture (thousand toe)		Economic and energy efficiency indicator for agriculture (million EUR·toe^{-1})		Change of indicator 2004 = 100
	2004	2016	2004	2016	2004	2016	
EU (28 countries)	197 881.20	209 115.70	27 519.60	24 078.10	7.19	8.68	20.78
Euro area (19 countries)	151 315.70	158 601.90	19 057.80	16 450.30	7.94	9.64	21.43
Belgium	3 037.00	2 696.20	816.00	772.80	3.72	3.49	–6.26
Bulgaria	1 769.90	1 951.50	276.00	185.10	6.41	10.54	64.41
Czech Republic	2 213.50	3 641.90	557.00	639.80	3.97	5.69	43.24
Denmark	3 284.30	2 810.70	690.70	629.70	4.76	4.46	–6.13
Estonia	334.70	452.40	104.80	127.30	3.19	3.55	11.28
Ireland	2 455.80	2 537.10	314.00	207.30	7.82	12.24	56.49
Greece	8 282.10	6 313.40	1 114.50	270.70	7.43	23.32	213.84
Spain	26 478.00	30 096.00	3 340.50	2 404.20	7.93	12.52	57.93
France	31 059.00	32 323.00	4 290.10	4 216.10	7.24	7.67	5.90
Croatia	1 498.30	1 462.60	206.40	205.90	7.26	7.10	–2.15
Italy	33 962.90	31 802.60	2 960.90	2 650.20	11.47	12.00	4.62
Cyprus	429.80	356.00	9.80	43.30	43.86	8.22	–81.25
Latvia	500.90	802.60	124.80	165.60	4.01	4.85	20.75
Lithuania	760.30	1 195.50	105.20	104.50	7.23	11.44	58.29
Luxembourg	154.80	119.40	21.40	24.40	7.23	4.89	–32.35
Hungary	3 597.50	4 410.40	586.00	647.40	6.14	6.81	10.97
Netherlands	9 878.00	12 513.00	3 771.10	3 687.60	2.62	3.39	29.54
Austria	3 578.20	3 963.90	546.60	520.10	6.55	7.62	16.42
Poland	6 733.00	10 154.90	4 292.60	3 540.40	1.57	2.87	82.87
Portugal	3 956.10	3 643.00	534.80	341.90	7.40	10.66	44.04
Romania	7 674.40	6 920.90	231.60	453.30	33.14	15.27	–53.92
Slovenia	633.10	785.10	74.00	73.20	8.56	10.73	25.36
Slovakia	1 264.40	2 731.80	161.60	148.40	7.82	18.41	135.27
Finland	3 778.00	5 143.00	736.80	687.40	5.13	7.48	45.91
Sweden	4 874.70	5 189.40	761.60	329.40	6.40	15.75	146.13
Great Britain	14 922.10	13 969.80	859.80	996.80	17.36	14.01	–19.25

Source: Authors' own study based on [Eurostat 2018e].

The global index of relative economic and energy efficiency (*GIREEE*) of agriculture against the country's economy was also calculated (Fig. 4). This indicator allows determining the effectiveness of agriculture in comparison with the effectiveness of the entire economy of the country. In 2016, the EU average was 0.746, which means that EU agriculture obtained a 25% lower gross value added per 1 t of oil equivalent than the EU economy as a whole. It is worrying that the indicator in 2006–2016 decreased, which means that the effectiveness of agriculture compared to the entire economy is relatively decreasing.

Noteworthy are 3 countries – Bulgaria, Greece and Romania, where the indicator was definitely above unity, which indicates that agriculture is relatively more energy-efficient than the entire economy. The reasons are relatively low energy consumption, which is the result of extensive agricultural practices, and lower production costs, which affect the amount of gross value added used in the calculations. On the other side of the list, there are countries with large-scale agriculture and high specialization (the Netherlands, Denmark). Nevertheless, the gross value added generated required several times higher energy expenditure than that generated in the whole economy.

CONCLUSIONS

Based on the conducted research, the following conclusions were formulated:

1. Energy consumption in EU agriculture has decreased for 25 years by around 30%, which, along with the growing value of gross production, is a positive phenomenon in the context of energy efficiency. The share of agriculture in total final energy consumption also decreased from 2.9% in 1990 to 2.2% in 2016. The highest share in 2016 was recorded in the Netherlands and Poland, at 7.4% and 5.3% respectively.
2. The most energetically intensive agriculture in the EU, calculated as final energy consumption per 1 ha of UAA, occurred in the Netherlands (nearly 4 times more energy per hectare of UAA than the second in Belgium and over 15 times more than the average in all EU countries). This is the result of very intensive agriculture and a high share of greenhouse production requiring high energy expenditure.
3. The agriculture of Greece and Slovakia had the highest economic and energy efficiency, generating the most gross value added from 1 ton of oil equivalent. These countries, together with Swe-

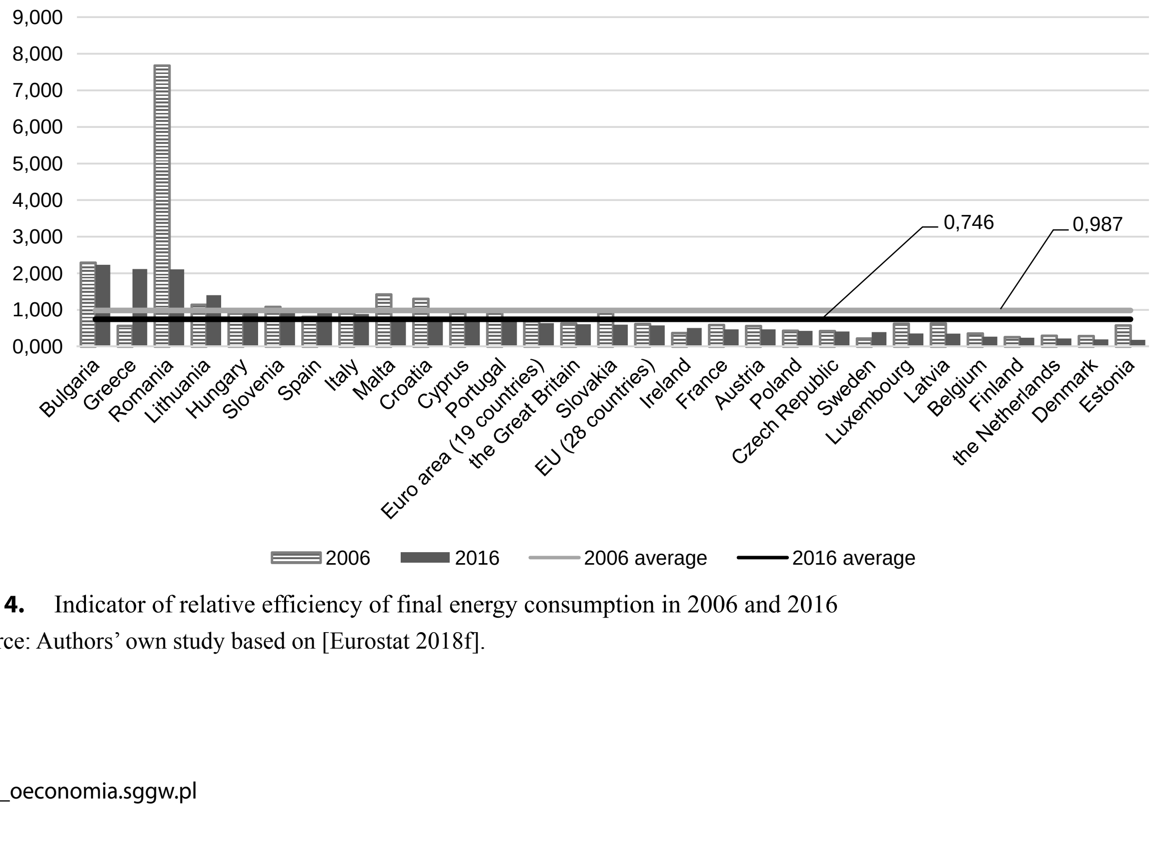


Fig. 4. Indicator of relative efficiency of final energy consumption in 2006 and 2016

Source: Authors' own study based on [Eurostat 2018f].

den, also had the greatest efficiency improvement in 2004–2016. Poland had the lowest efficiency in all EU countries. The high position of Greece may result from the structure of agriculture. The country is dominated by crops that generate high added value (citrus fruits) and use extensive production techniques, involving relatively less energy. In Slovakia, this may result from a high concentration of production, which in the case of energy consumption may have a positive impact and be a positive effect of scale.

4. The economic and energy efficiency of agriculture in the EU was on average 25% lower than the efficiency of the entire economy of the European Union. In three countries: Bulgaria, Greece and Romania, the indicator was definitely above unity, which indicates that agriculture is more effective there than the entire economy of the country. The reasons for this were relatively low energy consumption as a result of extensive farming practices and lower production costs that affect gross value added.

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EFEKTYWNOŚĆ EKONOMICZNO-ENERGETYCZNA ROLNICTWA W POLSCE NA TLE KRAJÓW UNII EUROPEJSKIEJ

STRESZCZENIE

Współczesne rolnictwo jest bezwzględnie uzależnione od zewnętrznych źródeł energii. Dominującą rolę w tym zakresie odgrywają nieodnawialne źródła energii, co przyczynia się do emisji gazów cieplarnianych i w konsekwencji degradacji środowiska naturalnego. Oczywiste staje się więc dążenie do poprawy efektywności wykorzystania energii oraz zmiany w strukturze źródeł jej pozyskiwania. Określenie efektywności ekonomiczno-energetycznej oraz ocena energochłonności rolnictwa w krajach UE były jednymi z głównych celów badawczych pracy. W artykule przeanalizowano zmiany zużycia energii w rolnictwie w przeliczeniu na zatrudnionego lub 1 ha użytków rolnych w całej Unii Europejskiej, a także w poszczególnych krajach członkowskich. Do analizy wykorzystano dane Eurostat.

Słowa kluczowe: ekonomia, energia, efektywność, rolnictwo, UE