Energy intensity in European Union countries after 2000

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DOI: 10.14595/CP/01/020

Abstract: The improvement of the functioning of the energy sector through increasing energy efficiency or decreasing energy intensity is a crucial challenge for all economies and their sectors. This results from the fact that the positive changes in this sector can contribute to higher economic development and improvement of economic welfare. The aim of the paper was to identify the tendencies in energy intensity in European Union countries, and their causes and effects since 2000. The hypothesis that with economic growth (measured by GDP per capita) the energy intensity of an economy decreases and energy consumption per capita falls too, was tested. Descriptive statistics methods, Pearson correlation coefficient and analysis of intensity (intensity indicators) were used in the paper. The changes in variables are presented mainly using dynamics and geometric mean indexes. The source of data is the European Commission, Eurostat and the World Bank. The hypothesis was proved in 20 countries and for the European Union as a whole. For 7 countries it was not proved (Austria, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Poland). Although some medium-developed countries increased the use of energy per capita during the period from 2000-2015 (Bulgaria, Estonia, Lithuania, Poland), these countries improved their energy efficiency much more (they reduced energy intensity). Finally, the effects are positive in these countries. There is the lowest energy intensity in highly-developed countries: Ireland, Denmark, United Kingdom, France, but there were the highest nominal and real decreases of energy intensity in countries with various GDPs (different GDP per capita levels): Ireland, Slovak Republic, Romania, Czech Republic, Bulgaria, Sweden, Poland. Among the most important determinants affecting the lower energy intensity belong restructuring of the economy and structural changes, technological changes, putting more capital into research and development and improvement of energy management systems.

Keywords: energy intensity, energy use, energy consumption, GDP

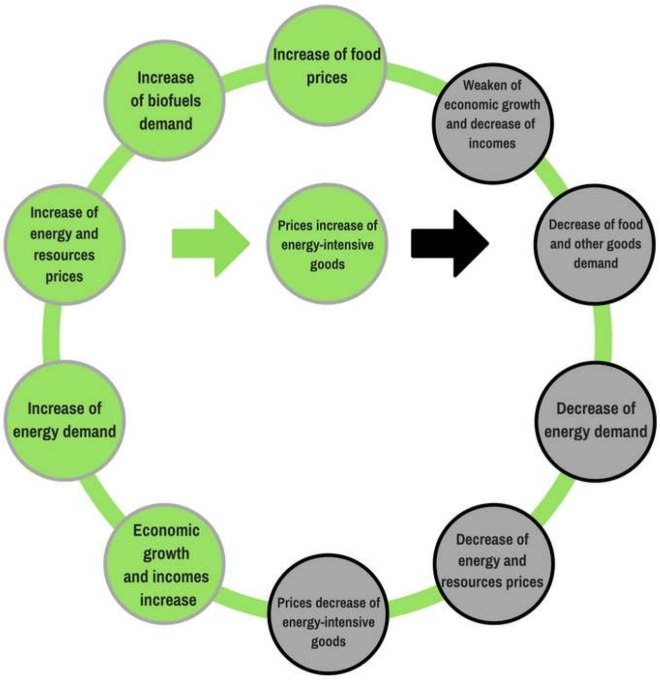
JEL: O13, Q43

Introduction

Currently economies strongly depend on energy resources (mainly crude oil, natural gas and coal) and their prices, which are determined on global markets by numerous and various factors, including economic, political and technological ones. In turn, changes in the prices of energy raw materials and energy are crucial for an economy, as their prices indirectly affect production costs, the prices of goods and services, and the competitiveness of the economy, and they also influence economic cycles, by determining their phases. This dependency becomes all the more significant and serious the more energy-intensive is the economy. As Hryszko and

Szajner point out [2013] (for Msangi, Tokgoz and Zhang 2012), the impact of energy price changes on the economic situation can be illustrated using a closed cycle (Figure 1). An increase in the prices of energy commodities and energy is accompanied by an increase in the prices of energy-intensive goods (due to higher production costs), which in turn leads to a decrease in demand for goods and services. Next, the demand for energy decreases and prices of energy commodities and energy decrease, too, assuming that significant changes do not occur on the supply side of energy raw materials and the energy market (e.g. supply shock). Prices of energy-intensive goods fall, due to the decrease in raw materials and energy prices (because production costs have fallen), which in turn contributes to increased consumer demand, and thus – economic growth [Filipović, Verbić and Radovanović 2018]. Therefore, as can be seen in the first figure described above, and as Maciejewski stresses [2017, p. 121], the low energy intensity[1] of an economy is a stimulus for its development, and therefore a reduction in energy intensity contributes to improving the efficiency of the economy [Rajbhandari and Zhang 2018].

Fig. 1. Influence of changes in prices of energy resources and energy in the business cycle



Source: Hryszko and Szajner (red.) 2013, p. 77 for: Msangi, Tokgoz and Zhang 2012.

[1] Energy intensity is measured as the amount of energy required per unit of output or activity. Similarly, energy efficiency is measured as the output per unit of energy used [U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy].

Energy intensity can be reduced, among others, by [Aydin and Esen 2018; Huang, Du and Tao 2017; Karimu et al. 2017; Tan and Lin 2018; Verbić, Filipović and Radovanović 2017; Wurlod and Noailly 2018]:

- higher efficiency of production factors;
- structural changes in the sectors of the economy, transforming energy-intensive industries;
- technological changes, technical efficiency, innovation in green technologies;
- energy-saving technology;
- capital-energy substitution;
- changes in the structure of commodities use (switch from fossil fuels to renewable energy sources);
- effective economic policy, including energy policy (energy prices, energy taxes).

Energy sector has strategic importance (as well as agriculture), because it is a commodity sector, thus changes in it have an influence on further sectors and industries of the economy. In that way, improvements in the functioning of this sector through increasing energy efficiency or decreasing energy intensity becomes a crucial challenge for an economy and its competitiveness [Choi, Park and Yu 2017]. Moreover, efficiency (the criterion of efficiency), which is the opposite of intensity, is of key importance to modern economics. It concerns the management of scarce resources (production factors including energy resources) and optimising their use for the production of goods and services [Staniszewski 2018].

According to Okun's law, every 1% over the natural rate of unemployment causes more than a 1% (about 2-3%) decrease in GDP [Okun 1962]. When we take into account the quite low unemployment rates in many European Union countries (Czech Republic 2.4%, Germany 3.5%, Hungary 3.7%, Netherlands 4.1%, UK 4.2%, Poland 4.4%, Romania 4.6% [Unemployment statistics]), it turns out that this is close to the natural rate of unemployment. In that situation there is no great potential for economic development (for GDP growth) through an increase of employment rates. There is little potential in the reduction of labour costs, in order to be more competitive in the global context, in many developing countries of the EU, as well. In this case, because of the high use of production factors, including land, labour and capital, improvement of the factors of productivity (including energy resources), organisational and technological changes and innovation seem to have the highest potential for an economy and its development. Mahmood and Ahmad [2018] stress that if Europe is able to exploit the maximum potential of energy efficiency, it will be able to gain significantly economically and environmentally over the next few decades. This can even be done on the basis of currently available technologies. Thus, the report underlines the importance of improving energy efficiency (by reducing energy intensity). It could have many benefits for the economy, society and environment [Aydin and Esen 2018].

According to Farajzadeh and Nematollahi [2018] determinants for the changing of energy intensity in developing countries are imported technologies and new devices for local firms. That situation played an important role especially in the early 2000's, as European countries opened up to other nations. Developed countries could export their energy-efficient devices to Central and Eastern European Countries like Poland, Latvia or Belarus. Another factor can be price changes. However they create a different result. According to the above-mentioned authors [Farajzadeh and Nematollahi 2018] and their literature review, there are some interesting conclusions. High energy prices are expected to lower energy intensity. Many studies focused on that issue. Barkhordari and Fattahi [2017] proved that increases in natural gas and electricity prices have both positive and negative impacts on energy intensity. A policy of increasing energy prices will result in increased consumption of gas which in the long term causes a decrease in energy intensity. People will change their main energy source for a more efficient one. Gas has proved to be more caloric, and much better in terms of calories-to-price ratio than coal. However, there are some contradictory opinions and research about it. Fisher-Vanden et al. [2004] created firm-level data in China. Their results are: an increase in the relative price of various energy prices causes an increase of energy intensity. On the other hand, Song and Zheng [2012] completed provincial-level data. They showed that there is only a weak positive effect between energy prices and energy intensity. Their conclusions were supported by Yang et al. [2016] who also revealed the same evidence. Farajzadeh and Nematollahi [2018] after research in Iran, concluded that one of main indicators lowering energy intensity is urbanisation and high capital-labour ratio. When capital accumulation occurs and the output mix is unchanged, we can expect higher incomes, which lead to higher energy intensity by lowering energy efficiency. As a country develops, more urbanised territories should be created. In urban area energy intensity decreases, because transfer can be more efficient. According to Farajzadeh, Zhu and Bakhshoodeh [2017], there is high potential at household level. Developing technologies become more efficient and do not need as much energy as old ones. Introducing them can result in a positive effect in terms of lowering energy intensity. According to Dong et al. [2018] we can look for a resolution to energy intensity problems in research and development investment when it comes to China. This conclusion has been repeated many times in other economic publications. Furthermore, the authors proved that urbanisation has a beneficial influence on energy intensity (decrease). That conclusion varies when we compare household, urban or national level. The researchers mentioned point out that the most important factor determining energy intensity and conservation of energy is economic structure (especially the structure of industry). A highly developed heavy industry sector will cause higher energy consumption. According to the paper by Liu et al. [2018] reducing the proportion of state-owned firms and increasing the amount of non-public enterprises in the heaviest industrial sectors can lower energy intensity. This will promote energy savings, ecological businesses and lower emissions. In addition, an increase in industrial concentration and integration of energy resources can reduce the energy intensity of heavy industry.

The importance of the energy intensity reduction is one of the main purposes of energy policy in the EU. The 2020 package is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets (the 3x20% package[2]): (1) a 20% cut in greenhouse gas emissions (from 1990 levels); (2) 20% of EU energy from renewables and a 10% share of renewables in the transport sector; (3) 20% improvement in energy efficiency. The most important benefits of achieving the goals of the 2020 package should be an increase in the EU's energy security – reducing dependence on imported energy and contributing to achieving a European Energy Union and create jobs, advance green growth and make Europe more competitive [2020 climate & energy package]. In turn, the 2030 climate and energy framework sets three key targets for the year 2030: (1) at least 40% cuts in greenhouse gas emissions (from 1990 levels); (2) at least a 27% share for renewable energy; (3) at least 27% improvement in energy efficiency [2030 climate & energy framework]. The long-term plans (for 2050) are as follows – the low-carbon economy roadmap suggests that by 2050 the EU should cut greenhouse gas emissions to 80% below 1990 levels [2050 low-carbon economy]. These assumptions are reflected in documents at national level – in EU countries, for example in Poland, where the climate and energy goal are formulated in the Polish Energy Policy until 2030 and Polish Energy Policy till 2050 or in the Czech Republic – National Climate Change Plan / Climate Protection Policy [International Energy Agency[3]].

Material and methods

The aim of the paper was to identify the tendencies in energy intensity in European Union countries, and their causes and effects. The focus is on the energy intensity viewed as the ratio between energy use and gross value added. It is hypothesised that with the economic growth of a country, the energy intensity of its economy decreases and energy consumption per

[2] The national targets under the 2020 climate & energy package: see Eurostat, Europe 2020 indicators.
[3] For crucial documents in countries – see the database of International Energy Agency.

capita falls, too. Such a hypothesis results from the fact that more developed EU countries (this development is measured using GDP per capita) are usually more efficient in the use of factors of production, including energy resources. As a result, these countries have lower energy intensity and higher energy efficiency. Therefore, as GDP per capita increases in EU countries, energy intensity should decrease. As regards energy consumption – it was assumed that energy consumption per capita is decreasing because of the fact that currently electronic devices are becoming more energy efficient (they use less energy).

According to the climate and energy package in some EU countries (mainly new member states) CO_2 emissions can increase, as the aim of 20% is overall and obligates the EU as a whole. These rising greenhouse gas emissions are directly connected with the increase of energy use, and this should be a consequence of economic growth and increased consumption of goods and services. In these cases, an improvement in energy intensity becomes an important challenge in order to meet the growing needs in those societies, and to face the problem of limited energy resources. At the same time, as it was mentioned, energy commodities and energy are necessary for economic growth (figure). The general formula for energy intensity is the ratio of energy use to gross value added (or Gross Domestic Product). In this paper, energy intensity is measured as the ratio of final energy consumption [in toe[4]] to gross value added [in 1 million USD in constant prices 2010].

$$Energy\ intensity = \frac{\text{final energy consumption [toe]}}{\text{gross added value [1 } M\text{\$2010]}}$$

According to Eurostat's methodology[5] final energy consumption is the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself [Eurostat, Statistics Explained, Glossary: Final energy consumption]. It is assumed in this paper that energy consumption includes final energy use (consumption) in agriculture, industry, services, transport and others[6] – thus, it is the use in production sectors of the economy. Therefore, the use of energy in residential[7] households was omitted. This was done in order to get a common structure – in gross added value in the economy, and in final energy

[4] toe = Tonne(s) of oil equivalent, is a normalised unit of energy. By convention it is equivalent to the approximate amount of energy that can be extracted from one tonne of crude oil. It is a standardised unit, assigned a net calorific value of 41 868 kilojoules/kg and may be used to compare the energy from different sources [Eurostat, Statistics Explained, Glossary: Tonnes of oil equivalent (toe)].
[5] There are more indicators on energy use on the macroeconomic level, i.e. gross inland consumption, primary energy consumption – see more: Eurostat, Statistics Explained.
[6] Services, transport and other are counted together as a service sector.
[7] In 2015 it amounted, depending on the country, to 19-36% of total final energy consumption [European Commission].

consumption by individual sectors. For the hypothesis there are two variables used: (1) economic growth, which is measured as the changes in Gross Domestic Product (GDP) per capita at 2010 USD constant prices and (2) energy use per capita – in kg of oil equivalent, which is calculated as gross inland energy consumption[8] per capita. Data on GDP and gross value added are in constant prices (USD) from 2010, thus the impact of inflation was eliminated. In the paper the term "medium-developed" countries of the EU is used – this refers to the European Union's average level of GDP, and to the best countries in this area (with the highest income per capita). It does not concern third world countries (developing countries all over the world). Thus, medium-developed countries are, for example, Poland, Czech Republic, Slovak Republic or the Baltic states. The research period is 2000-2015 and all European Union countries are analysed (except Malta – because of a lack of data). Descriptive statistics methods, Pearson correlation coefficient and analysis of intensity (intensity indicators) were used in the paper. The changes in variables are presented mainly using dynamics and geometric mean[9] indexes. The source of data is the European Commission and Eurostat – mainly data on energy use (by sector – agriculture and fishing, industry, services, transport, residential, others) and the World Bank – data on gross value added (in agriculture, industry, services and total), Gross Domestic Product (per capita, constant prices 2010 USD) and energy use (per capita). Calculations were made using MS Office Excel and Statistica.

Results and discussion

In 2000, the highest energy intensity was in new member states (those that acceded to the EU in 2004 or 2007): Bulgaria (about 250 toe/1 million USD), Slovak Republic (170), Romania (150), Czech Republic, Latvia, Poland (over 130). On the other hand, the lowest level of energy intensity was in 2000 in Denmark (41 toe/1 million USD), Italy, France, Germany, Ireland – about 52-57 toe/1 million USD, i.e. primarily in the high-developed countries of the European Union (table 1). The situation did not change much in 2015. There is low energy intensity in rich countries, however, some countries changed places – Ireland (under 30 toe/1 million USD), Denmark (33), United Kingdom (39) and France (42 toe). The highest level

[8] Gross inland energy consumption, sometimes abbreviated as gross inland consumption, is the total energy demand of a country or region. It represents the quantity of energy necessary to satisfy the inland consumption of the geographical entity under consideration. Gross inland energy consumption covers: (a) consumption by the energy sector itself; (b) distribution and transformation losses; (c) final energy consumption by end users; (d) statistical differences (not already captured in the figures on primary energy consumption and final energy consumption). See Eurostat, Statistics Explained, Glossary: Gross inland energy consumption.

[9] The geometric mean is very useful when values tend to make large fluctuations. If statistical data inform about average increments of the examined value in relation to the previous period, the geometric mean is more appropriate than the arithmetic mean or median for examining the average rate of change of phenomena, for example growth rates, returns on portfolio of securities.

of energy intensity in 2015 was in Bulgaria (156 toe/1 million USD), Latvia (109), Estonia (95), Hungary (92) and Finland (90). According to research done by Locmelis et al. [2016] we can identify the main reasons for the still existing high level of energy intensity in some countries. There are high energy prices in Latvia (as high as in Germany), but the Latvian economy is less efficient. It is worth noting that prices increased by nearly 50% between 2010 and 2015. The result, in this situation, is high energy intensity. Over 25% of energy in Latvia is used in industrial sectors, from which 85% is consumed by only 4 of the most valuable industry sectors: manufacturing of wood, food, non-metallic mineral products and manufacturing of fabricated metal products. Therefore, there is high potential in making the Latvian industrial sector more energy efficient. As the authors mentioned conclude – the general aim of energy policy should be decreasing energy intensity through the implementation of new, accurate energy management systems which are measurable and have precise monitoring methods. This solution should lead the country to gain greater control over its energy sector and should ease decreasing energy intensity. Moreover, after the financial crisis in 2008, Latvia restructured its own economic sectors. After that, there appeared high energy demanding industrial sectors. According to Gamtessa and Olani [2018] the green gas emission problem is the main issue of many energy policies. After the launch of many environmental (ecology) movements in global politics, we can observe a decrease of energy intensity and improvement (higher efficiency) in energy production.

There is an interesting situation in Finland – the energy intensity amounted in 2000 to almost 107 toe/1 million USD – similar to Slovenia, and much more than other highly-developed countries. In 2015 it was over 90 toe, thus Finland is among the most energy-intensive economies in the EU. However it is due to the fact that there are very energy-intensive industries in this country, especially the forestry industry, which is responsible for about 50% of energy use in the industrial sector [Zakeri, Syri and Rinne 2015]. The European Union has energy intensity at a level of 64 toe/1 million USD and it amounted 50 toe in 2015. There is a moderate/strong negative relationship between GDP per capita level and energy intensity. The Pearson correlation coefficient was -0.63 in 2000 and -0.61 in 2015, which means that the more developed (the richer) the country, the lower is the energy intensity of its economy. However, it is worth noticing that the tendencies and changes in energy intensity (its decreases) do not follow such a simple relationship.

The highest progress in reducing energy intensity was mainly made by less- or medium-developed countries of the European Union. The annual decreases in energy intensity (measured through geometric means of changes in the period 2000-2015) amounted to 4.4%

in Ireland, 4.2% in the Slovak Republic, 3.5% in Romania, 3.1% in Czech Republic, 3% in Bulgaria, 2.9% in Sweden and 2.6% in Poland (tables 2 and 3). When we take into account the change in energy intensity in 2015 compared to 2000 (table 1), the values of this indicator decreased in Ireland and the Slovak Republic by almost 50% (Ireland: by 28 toe, from 57 to 29 toe/1 million USD and Slovak Republic: by 80 toe, from 168 to 88 toe) and by 33-41% in Romania (a decrease of 61 toe), Czech Republic (52 toe), Bulgaria (91 toe), Sweden (28 toe), Poland (44 toe) and Great Britain (19 toe). In the European Union, energy intensity decreased every year by 1.58% and across the whole analysed period by 21.3% (from 64 to 50 toe/1 million USD).

Table 1. Energy intensity in toe/1 million USD [constant 2010], GDP per capita [constant 2010 USD] and energy use per capita in kg of oil equivalent in the European Union countries in 2000-2015 and changes 2015/2000

Specification	Energy intensity in toe/1 million USD [constant 2010]				GDP per capita [constant 2010 USD]				Energy use per capita in kg of oil equivalent			
	2000	2008	2015	2015 / 2000	2000	2008	2015	2015 / 2000	2000	2008	2015	2015 / 2000
Austria	58,12	61,41	58,03	99,8%	42 123	48 028	47 835	113,6%	3 570	4 032	3 804	106,6%
Belgium	76,48	64,74	60,57	79,2%	40 170	44 956	45 068	112,2%	5 669	5 455	4 688	82,7%
Bulgaria	247,53	179,61	156,14	63,1%	4 011	6 914	7 612	189,8%	2 277	2 649	2 478*	108,8%
Croatia	93,19	86,36	83,63	89,7%	10 570	14 779	13 936	131,8%	1 895	2 216	1 898*	100,2%
Cyprus	88,21	72,40	64,79	73,5%	27 318	32 652	27 587	101,0%	2 265	2 389	1 712*	75,6%
Czech Republic	137,30	101,70	85,55	62,3%	14 807	20 521	21 382	144,4%	3 988	4 331	3 860	96,8%
Denmark	40,62	38,87	32,96	81,1%	55 851	60 505	59 968	107,4%	3 490	3 502	2 817	80,7%
Estonia	122,87	108,70	94,98	77,3%	10 108	16 717	17 734	175,4%	3 375	4 105	4 173	123,7%
European Union	63,69	56,35	50,13	78,7%	30 293	34 671	35 230	116,3%	3 472	3 512	3 207	92,4%
Finland	106,96	89,42	90,38	84,5%	40 450	49 364	45 087	111,5%	6 262	6 669	5 925	94,6%
France	54,32	47,45	42,42	78,1%	38 522	41 545	41 690	108,2%	4 135	4 111	3 688	89,2%
Germany	55,84	49,98	47,71	85,4%	37 998	42 365	45 413	119,5%	4 094	4 037	3 818	93,2%
Greece	63,32	55,66	55,22	87,2%	23 275	29 875	22 649	97,3%	2 507	2 745	2 182	87,1%
Hungary	116,10	97,20	92,26	79,5%	10 490	13 869	14 629	139,5%	2 448	2 637	2 433	99,4%
Ireland	57,06	48,68	29,14	51,1%	42 945	50 918	67 590	157,4%	3 627	3 294	2 835	78,2%
Italy	52,45	50,59	44,92	85,7%	36 181	37 585	33 984	93,9%	3 012	3 088	2 482	82,4%
Latvia	135,51	107,37	109,04	80,5%	6 935	13 270	14 294	206,1%	1 618	2 106	2 177*	134,5%

Specification	Energy intensity in toe/1 million USD [constant 2010]				GDP per capita [constant 2010 USD]				Energy use per capita in kg of oil equivalent			
	2000	2008	2015	2015 / 2000	2000	2008	2015	2015 / 2000	2000	2008	2015	2015 / 2000
Lithuania	109,92	92,86	87,41	79,5%	6 934	13 405	15 342	221,3%	2 038	2 976	2 387*	117,2%
Luxembourg	82,48	81,01	64,10	77,7%	93 463	108 577	107 649	115,2%	7 677	8 612	6 548	85,3%
Netherlands	63,53	55,96	49,36	77,7%	46 133	52 118	51 410	111,4%	4 739	4 848	4 233	89,3%
Poland	132,62	108,25	88,77	66,9%	8 525	11 800	14 640	171,7%	2 320	2 565	2 490	107,3%
Portugal	78,39	72,32	66,42	84,7%	21 513	22 830	22 017	102,3%	2 390	2 337	2 132	89,2%
Romania	146,82	103,65	86,10	58,6%	4 901	8 873	9 567	195,2%	1 614	1 929	1 592*	98,6%
Slovak Republic	168,14	114,48	88,44	52,6%	10 297	16 748	18 679	181,4%	3 293	3 406	3 004	91,2%
Slovenia	105,08	93,18	83,04	79,0%	18 571	25 447	23 731	127,8%	3 224	3 837	3 175	98,5%
Spain	64,68	58,34	50,50	78,1%	28 335	32 303	30 531	107,7%	3 004	3 026	2 571	85,6%
Sweden	79,24	60,12	51,23	64,7%	44 694	52 711	55 395	123,9%	5 360	5 380	5 103	95,2%
United Kingdom	58,33	46,93	39,09	67,0%	35 577	40 536	41 537	116,8%	3 786	3 362	2 764	73,0%

* Data on energy use per capita in 2015 in Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Romania – these are data from 2014.

Source: Own study based on data: European Commission, DG ENER, Energy Statistics, By country, Country datasheets: EU-28; The World Bank, Data Bank, World Development Indicators (see references).

At the bottom of this ranking are mainly high-developed EU countries and PIGS-countries[10]. Energy intensity decreased in the years 2000-2015 in Croatia by 10%, Germany by 14.6%, in Denmark and Finland by 15.5-18.9% only. Interestingly, in Austria, energy intensity was at the same level in 2015 as in 2000 (58 toe/1 million USD), thus, in Austria there was no progress in this area. In turn, in the PIGS-countries this ratio fell during the analysed period by only 13-15%. Annual changes (decreases of energy intensity) in Portugal, Italy and Greece did not exceed 1.1%.

In transition economies (especially in the countries of East-Central Europe) the main reasons for energy intensity decreases after 1990 were [European Environment Agency; Petrović, Filipović and Radovanović 2018; Timma, Zoss and Blumberga 2016; Verbić, Filipović and Radovanović 2017; Wysokiński, Trębska and Gromada 2017, p. 239]:

[10] PIGS is acronym used regarding to 4 countries: Portugal, Italy, Greece, Spain, in which the debt crisis and as well the economic crisis had the most negative consequences after 2008/2009. Sometimes there is used broader acronym "PIIGS", which encompasses these countries and Ireland, however it is not very precise, because Ireland only had an economic recession in the period 2007-2009, and these other countries – much longer [The World Bank].

- restructuring of the national economy and change in the structure of the economy (in the sense of the three sector theory of Fisher, Clark and Fourastie [Zajdel 2011]);
- technological changes, according to which new technologies (machines, and devices)were introduced which were resource-efficient, including more energy-efficient ones;
- changes in the structure of energy commodities consumption, including decreasing consumption of coal in favour of growing consumption of hydrocarbon fuels and renewable energy sources;
- privatisation in an economy that fosters energy efficiency;
- improvement of energy efficiency in manufacturing branches and in the electricity and heat industries;
- improvement of energy efficiency in housing and industry;
- consistent implementation of EU regulations and support from EU structural funds (especially after 2004);
- and – to some extent – reduction of fuel consumption in transport through higher efficiency in logistics and implementation of new technologies in transport.

Table 2. Geometric means of changes (year to year) for three variables: energy intensity, GDP per capita and energy use per capita, in %, in the period 2000-2015 (rejection of the hypothesis)

Specification	Geometric mean of changes (year to year) in energy intensity in %	Geometric mean of changes (year to year) in GDP per capita in %	Geometric mean of changes (year to year) in energy use per capita in %
Austria	-0,01%	0,85%	0,42%
Bulgaria	-3,03%	4,36%	0,60%
Croatia	-0,72%	1,86%	0,01%
Estonia	-1,70%	3,82%	1,43%
Latvia	-1,44%	4,94%	2,14%
Lithuania	-1,52%	5,44%	1,14%
Poland	-2,64%	3,67%	0,47%

Source: Own study based on the data from table 1.

Table 3. Geometric means of changes (year to year) for three variables: energy intensity, GDP per capita and energy use per capita, in %, in the period of 2000-2015 (confirmation of the hypothesis)

Specification	Geometric mean of changes (year to year) in energy intensity in %	Geometric mean of changes (year to year) in GDP per capita in %	Geometric mean of changes (year to year) in energy use per capita in %
Belgium	-1,54%	0,77%	-1,26%
Cyprus	-2,04%	0,07%	-1,98%
Czech Republic	-3,10%	2,48%	-0,22%
Denmark	-1,38%	0,48%	-1,42%
European Union	-1,58%	1,01%	-0,53%
Finland	-1,12%	0,73%	-0,37%
France	-1,64%	0,53%	-0,76%
Germany	-1,04%	1,20%	-0,47%
Greece	-0,91%	-0,18%	-0,92%
Hungary	-1,52%	2,24%	-0,04%
Ireland	-4,38%	3,07%	-1,63%
Italy	-1,03%	-0,42%	-1,28%
Luxembourg	-1,67%	0,95%	-1,05%
Netherlands	-1,67%	0,72%	-0,75%
Portugal	-1,10%	0,15%	-0,76%
Romania	-3,49%	4,56%	-0,10%
Slovak Republic	-4,19%	4,05%	-0,61%
Slovenia	-1,56%	1,65%	-0,10%
Spain	-1,64%	0,50%	-1,03%
Sweden	-2,87%	1,44%	-0,33%
United Kingdom	-2,63%	1,04%	-2,08%

Source: Own study based on the data from table 1.

Considering the empirical data on energy intensity in the sectors of the economy and the use of energy per capita in 2015, it can be concluded that there is no significant link between these variables. There are countries with high levels of energy use per capita and with both – quite low (Sweden, Netherlands) and high (Finland, Estonia, Czech Republic) levels of energy intensity. In turn, obviously, there is a positive relationship (Pearson correlation coefficient close to 0.7) between energy use per capita and GDP per capita in 2015. The more developed the economy, the higher the energy consumption – good examples are Luxembourg, Netherlands, Sweden, but on the other side, there are highly-developed countries with low energy consumption per capita level (Denmark, Ireland). These are, however, very rich countries, based on effective ecological processes. Although there is a tendency in most European Union countries that GDP is growing and energy use per capita is decreasing, because production processes and the efficiency of machines and devices are improving, as it was mentioned, some less- and medium-developed European Union countries could increase CO_2 emissions in order to reduce the economic gap between themselves and the best countries. These are countries in which the energy consumption per capita increased during 2000-2015, but where they improved energy efficiency (they decreased the energy intensity) much more, therefore the final effects are positive. Such a situation concerns Bulgaria, Croatia, Estonia, Lithuania and Poland.

Conclusions

The aim of the paper was to identify the tendencies in energy intensity in the European Union countries and their causes and effects. The focus has been on energy intensity as the ratio between energy use and gross value added. The following hypothesis was tested: with economic growth, the energy intensity of an economy decreases and energy consumption per capita decreases, too. The hypothesis was confirmed in 20 countries and for the European Union as a whole. For 7 countries it was rejected (Austria, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Poland). The lowest energy intensity is in highly-developed countries: Ireland, Denmark, United Kingdom, France, but there were the highest nominal and real decreases of energy intensity in countries with different GDPs (different GDP levels): Ireland, Slovak Republic, Romania, Czech Republic, Bulgaria, Sweden, Poland. The lower the energy intensity, the more ecological the economy. However, not all highly-developed European Union countries have low energy intensity (e.g. Finland, Luxembourg, Belgium, Austria).

Although the use of energy increased during the period 2000-2015 in some medium-developed countries of the European Union (Bulgaria, Estonia, Lithuania, Poland), these countries improved energy efficiency much more (they reduced the energy intensity). Ultimately, the effects are positive in these countries. An increase in energy use per capita was observed in countries in which there were the highest GDP growth rates. Higher energy consumption resulted from dynamic economic development. This can be connected with the catch-up effect (convergence).

Putting more capital into research and development (R&D) investment can lead to a decrease in energy intensity. Furthermore, this will promote energy efficiency. Countries should possess, or introduce new energy management systems which are measurable, transparent and easy to control. This could support improving energy efficiency in the long term. Another important determinant for decreasing energy intensity are: restructuring of the national economy, structural and technological changes, privatisation of the economy. State policy can play special role in the support of entities (companies, households) in order to achieve these changes through structural funds (European Union funds) or implementing a loan and credit system for energy efficiency. The final effect of these activities would be lower energy intensity and higher efficiency of production factors, which could lead to an increase in national income and economic welfare.

References

2020 climate & energy package, https://ec.europa.eu/clima/policies/strategies/2020_en, access: 04.2018.

2030 climate & energy framework, https://ec.europa.eu/clima/policies/strategies/2030_en, access: 04.2018.

2050 low-carbon economy, https://ec.europa.eu/clima/policies/strategies/2050_en, access: 04.2018.

AYDIN, C., ESEN, Ö., (2018). *Does the level of energy intensity matter in the effect of energy consumption on the growth of transition economies? Evidence from dynamic panel threshold analysis*, Energy Economics, vol. 69, p. 185-195.

BARKHORDARI, S., FATTAHI, M., (2017). *Reform of energy prices, energy intensity and technology: A case study of Iran (ARDL approach),* Energy Strategy Reviews, vol. 18, p. 18-23.

CHOI, B., PARK, W., YU, B. K., (2017). *Energy intensity and firm growth*, Energy Economics, vol. 65, p. 399-410.

DONG, K., SUN, R., HOCHMAN, G., LI, H., (2018). *Energy intensity and energy conservation potential in China: A regional comparison perspective*, Energy, vol. 155, p. 782-795.

European Commission, DG ENER, Energy Statistics, By country, Country datasheets: EU-28, update: August 2017, https://ec.europa.eu/energy/en/data-analysis/country, access: 04.2018.

European Environment Agency, EN21 Final Energy Consumption Intensity.

Eurostat, Europe 2020 indicators – Headline indicators – Climate change and energy, http://ec.europa.eu/eurostat/web/europe-2020-indicators/europe-2020-strategy/main-tables, access: 04.2018.

Eurostat, Statistics Explained, Category: Energy glossary, http://ec.europa.eu/eurostat/statistics-explained/index.php/Category:Energy_glossary, access: 04.2018.

Eurostat, Statistics Explained, Glossary: Final energy consumption, http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Final_energy_consumption, access: 04.2018.

Eurostat, Statistics Explained, Glossary: Gross inland energy consumption, http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary: Gross_inland_energy_consumption, access: 04.2018.

Eurostat, Statistics Explained, Glossary: Tonnes of oil equivalent (toe), http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Tonnes_of_oil_equivalent_(toe), access: 04.2018.

FARAJZADEH, Z., NEMATOLLAHI, M. A., (2018). *Energy intensity and its components in Iran: Determinants and trends*, Energy Economics (Accepted Manuscript).

FARAJZADEH, Z., ZHU, X., BAKHSHOODEH, M., (2017). *Trade reform in Iran for accession to the World Trade Organization: Analysis of welfare and environmental impacts*, Economic Modelling, vol. 63, p. 75-85.

FILIPOVIĆ, S., VERBIĆ, M., RADOVANOVIĆ, M., (2015). *Determinants of energy intensity in the European Union*: A panel data analysis, Energy, vol. 92, p. 547-555.

FISHER-VANDEN, K., JEFFERSON, G. H., LIU H., TAO, Q., (2004). *What is driving China's decline in energy intensity?* Resource and Energy Economics, vol. 26, p. 77-97.

GAMTESSA, S., OLANI, A. B., (2018), *Energy price, energy efficiency, and capital productivity: Empirical investigations and policy implications*, Energy Economics, vol. 72, p. 650-666.

HRYSZKO, K., SZAJNER, P. (ed.), (2013). *Sytuacja na światowym rynku cukru i jej wpływ na możliwości uprawy buraków cukrowych w Polsce*, Program Wieloletni 2011-2014, nr 71, Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej – Państwowy Instytut Badawczy, Warszawa.

HUANG, J., DU, D., TAO, Q., (2017). *An analysis of technological factors and energy intensity in China*, Energy Policy, vol. 109, p. 1-9.

International Energy Agency, Member countries, https://www.iea.org/countries/membercountries/, access: 04.2018.

KARIMU, A, BRÄNNLUND, R., LUNDGREN, T., SÖDERHOLM, P., (2017). *Energy intensity and convergence in Swedish industry: A combined econometric and decomposition analysis*, Energy Economics, vol. 62, p. 347-356.

LIU, K., BAI, H., WANG, J., LIN, B., (2018). *How to reduce energy intensity in China's heavy industry – Evidence from a seemingly uncorrelated regression,* Journal of Cleaner Production, vol. 180, p. 708-715.

LOCMELIS, K., BARISS, U., BLUMBERGA, D., (2016). *Latvian energy policy on energy intensive industries*, Energy Procedia, vol. 113, p. 362-368.

MACIEJEWSKI, M., (2017). *Zróżnicowanie kondycji gospodarczej państw Unii Europejskiej*, Studia Ekonomiczne, Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, Nr 319, p. 117-126.

MAHMOOD, T., AHMAD, E., (2018). *The relationship of energy intensity with economic growth: Evidence for European economies*, Energy Strategy Reviews, vol. 20, p. 90-98.

MSANGI, S., TOKGOZ, S., ZHANG, W., (2012). *Biofuels, Agriculture and Food Security: Key Connections & Challenges*, Environment & Production Technology Division, IFPRI, Washington.

OKUN, A. M., (1962). *Potential GNP: Its Measurement and Significance*, Cowles Foundation Paper no. 190.

PETROVIĆ, P., FILIPOVIĆ, S., RADOVANOVIĆ, M., (2018). *Underlying causal factors of the European Union energy intensity: Econometric evidence*, Renewable and Sustainable Energy Reviews, vol. 89, p. 216-227.

RAJBHANDARI, A., ZHANG, F., (2018). *Does energy efficiency promote economic growth? Evidence from a multicountry and multisectoral panel dataset*, Energy Economics, vol. 69, p. 128-139.

SONG, F., ZHENG, X., (2012). What drives the change in China's energy intensity: Combining decomposition analysis and econometric analysis at the provincial level, Energy Policy, vol. 51, p. 445-453.

STANISZEWSKI, J., (2018). *Wpływ struktur wytwórczych na zrównoważoną intensyfikację produkcji rolnej w krajach Unii Europejskiej po 2004 roku*, Rozprawa doktorska, Uniwersytet Ekonomiczny w Poznaniu.

TAN, R., LIN, B., (2018). *What factors lead to the decline of energy intensity in China's energy intensive industries?*, Energy Economics, vol. 71, p. 213-221.

The World Bank, DataBank, World Development Indicators, http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators#, access: 04.2018.

TIMMA, L., ZOSS, T., BLUMBERGA, D., (2016). *Life after the financial crisis. Energy intensity and energy use decomposition on sectorial level in Latvia*, Applied Energy, vol. 162, p. 1586- 1592.

Unemployment statistics, http://ec.europa.eu/eurostat/statistics-explained/index.php/Unemployment_statistics#Main_statistical_findings, access: 04.2018.

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Energy Intensity Indicators: Efficiency vs. Intensity, https://www.energy.gov/eere/analysis/energy-intensity-indicators-efficiency-vs-intensity, access: 12.06.2018.

VERBIĆ, M., FILIPOVIĆ, S., RADOVANOVIĆ, M., (2017). *Electricity prices and energy intensity in Europe*, Utilities Policy, vol. 14, p. 58-68.

WURLOD, J. D., NOAILLY, J., (2018). *The impact of green innovation on energy intensity: An empirical analysis for 14 industrial sectors in OECD countries*, Energy Economics, vol. 71, p. 47-61.

WYSOKIŃSKI, M., TRĘBSKA, P., GROMADA, A., *Energochłonność polskiego rolnictwa na tle innych sektorów gospodarki (Polish agriculture energy intensity with other economic sectors)*, Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu, tom XIX, zeszyt 4, p. 238-243.

YANG, G., LI, W., WANG, J., ZHANG, D., (2016). A comparative study on the influential factors of China's provincial energy intensity, Energy Policy, vol. 88, p. 74-85.

ZAJDEL, M., (2011). *Trójsektorowa struktura gospodarcza w Polsce jako miernik rozwoju (wybrane aspekty)*, Nierówności Społeczne a Wzrost Gospodarczy, Nr 18, p. 419-430.

ZAKERI, B., SYRI, S., RINNE, S., (2015). *Higher renewable energy integration into the existing energy system of Finland – Is there any maximum limit?*, Energy, vol. 92, p. 244-259.