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# Energy Production and Consumption in the European Union - Assessment of Changes in the Aspects of Sustainability and the Energy Self-Sufficiency

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Mariusz Dacko[1], Łukasz Paluch[2], Bartosz Mickiewicz[3], Paweł Mickiewicz[4], Maciej Nowak[5]

***Abstract:***

***Purpose:*** *The study discusses the issue of energy sustainability of the EC countries from the point of view of renewable energy sources, energy consumption and energy dependence and general energy demand of the economy. The study aims to identify and evaluate the key characteristics of the energy sector of the European Union countries in 2016.*
***Design/Methodology/Approach:*** *The information used in the comparative analysis includes the data published in EUROSTAT and the BP Statistical Review of World Energy reports. The data applied to the characteristics of global trends in energy production and consumption in regards to self-sufficiency and sustainability of the energy sector im EU.*
***Findings:*** *The analysis shows that despite the common challenges, the membership countries show significantly different levels of completion of climate and energy goals established by the E. The EC countries often represent different approaches to the issues related with the production and consumption of primary energy. The first approach can be observed in most Western European countries in which the energy production is mainly based on renewable sources and meet a minor part of the economy's energy demand. The second approach is represented by the Central and Eastern European countries and focus on self-sufficiency and security of their own energy systems in which the production of primary energy is better balanced with consumption, however, the contribution of renewable sources is small.*
***Practical Implications:*** *The recommendations resulting from the analyses may be used as a valuable source of information for the entities and institutions responsible for developing the tasks undertaken as part of the environmental policies.*
***Originality/Value:*** *The results supplement previous research on the analysis of sustainability and self-sufficiency of the energy sector of the EU countries.*

***Keywords:*** *Energy, resource economics, consumption, renewable sources, self-sufficiency.*

***JEL codes:*** *H7, L52, L78, O13, O44, Q2, Q3.*

***Paper Type:*** *Research study.*

[1]*PhD University of Agriculture in Krakow, Faculty of Agriculture and Economics,* MARIUSZ.DACKO@URK.EDU.PL;
[2]*PhD same as in 1,* LUKASZ.PALUCH@URK.EDU.PL
[3]*Professor, West Pomeranian University of Technology in Szczecin, Faculty of Economics,* bartosz.mickiewicz@zut.edu.pl
[4]*Professor, same as in 3,* pawel.mickiewicz@zut.edu.pl
[5]*Professor, same as in 3,* maciej.nowak@zut.edu.pl

## 1. Introduction

In the mid-20th century, by observing the trends in the global economy, a French economist Jean Fourastie proclaimed that nothing will be less industrial than the civilization born of the industrial revolution (Fourastie, 1972). Was he right? The world has made a switch from the Industrial Age into the Super-industrial Age which, in many ways, are totally different. Knowledge and intellect became the key factors in the production processes (Toffler, 1995; Cempel, 2006; Szmal, 2011; Beyer, 2011), and the time between the stages of the invention cycle has shortened significantly. In the information societies connected through a global network new ideas are applied much faster and spread much easier than ever before (Toffler, 2007) to become a source for other creative solutions. Time and distance, as proposed by Hägerstrand and discussed in the studies by economic geographers, have a minor impact on the diffusion of innovations as the main factors determining the progress of civilisation (Kuciński, 1994; Domański, 2004).

Modern technologies also moderate the effect of other obstructions, for example the language barriers, in these processes. An invention in one field may open unlimited possibilities of new combinations and applications, usually in very different areas of human life. As a result, according to the Secretary-General of the United Nations, Sithu U Thanta, in this new age of civilization progress, the resources are no longer a limiting factor for human decisions. Rather, the human decisions determine and decide on the resources. Depending on the context, this statement can be optimistic or can provoke reflections and anxieties. An ability to overcome the resource barriers using modern technologies and substitute non-renewable and depletable resources with non-depletable and renewable resources gives the humanity new prospects for further economic growth. Despite the inventiveness and creativity, the economy of the Super-industrial Age (similar to the Industrial Age) is still heavily dependent on fossil fuels and the statistics for energy consumption may be alarming (Brown, 2001; Berdo, 2006).

In the mid-20th century, an Indian nuclear physicist, Homi Bhabha estimated that half of the total energy consumption in the last two thousand years occurred in the last one hundred years (Toffler, 2007), and the disproportion grows with each decade. When and what can we expect as a result of the continues unlimited economic growth on a planet with limited resources? Will humanity learn to obtain energy in a way used by the natural ecosystems before the fossil fuels run out? How should the production and consumption of energy look like from the point of view of the European Community? Is limiting production of own energy and relying on imports of energy sources at an oligopolistic market a threat to sustainable development? Should we bear additional costs to balance this important area of economic and social life of every single country in the world? The authors of the study attempt to answer these questions based on a review of scientific publications and international statistics.

## 2. Global Trends in Energy Consumption

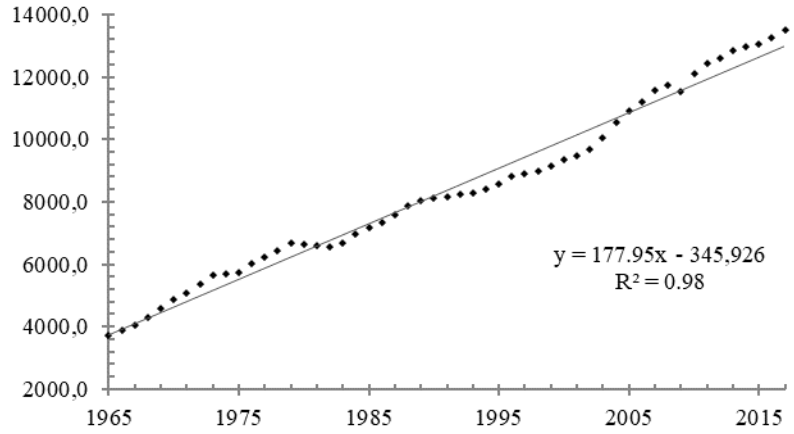
A constant need to consume energy is one of the biggest addictions of the modern civilisation. In 2017, according to the BP Statistical Review of World Energy report, over 13,500 Mtoe[6] of energy was consumed, and the global consumption increases by 178 Mtoe/year. In the last 50 years, the energy consumption has increased globally by more than 400% (Berdo, 2006). According to The World Counts website, our civilisation uses so many resources that to continue this trend, we will soon need another Earth (The World Counts, 2019). The World Counts expresses alarm over the Earth's resources turned to waste at an insane rate. A continuation of this rate, characterized by a regression equation (Figure 1), throughout the 100 years will result in an increase in global energy consumption from 3,700 Mtoe in 1965 to over 22,000 Mtoe in 2065. But before that happens, according to the Meadows team (1973), the humanity will reach the resource availability barrier.

At the beginning of the 19th century, an American environmental analyst Brown (2003) presented a suggestive example relating to the resources: if from the beginning of a new millennium the citizens of China would like to use their cars and consume the same amount of petrol as the Americans, China would use over 80 million oil barrels a day, which is more than the global production estimated at 74 million oil barrels. The amount of oil is sufficient for now, but the moment in which the output is at its maximum is not as far away as we would like to think (Brown, 2001). A non-linear model developed by Norouzi *et al.* (2019) shows that the global energy demand and supply should be ready for this in the 3rd decade of the 21st century. In this context, we may cite the opinion of Klingholz, a German chemist and journalist, stating that the fears of depleting the energy sources are understandable as nothing will work without a continuous supply of energy in an industrial society (Bertrand, 2002). And those supplies are still highly dependent on limited and depletable fossil fuels (Ripple *et al.,* 2019) including coal, oil natural gas, uranium or lithium (Pociovalisteanu *et al.,* 2010).

According to Tinbergena, an economist and Nobel laureate, two things are infinite: the number of generations we should feel responsible for and our ingenuity. The first is a challenge, as it requires us to stop thinking in short-term cost-benefit categories. The second can create innovations and ideas that can meet the challenge half way (Schultink, 2007). Human creativity can overcome the barriers of further growth in energy production. Paradoxically, the ever growing greenhouse effect, with its adverse climate-related consequences, may open some unexpected possibilities of obtaining the energy carriers. We know, for example, about the large quantities of methane stored in the Arctic (Kronenberg and Bergier 2010; Douglas *et al.,* 2016).

[6]*Millions of tonnes of oil equivalent, i.e. the energy equivalent to one tonne of oil with a calorific vale of 10,000 kcal/kg (1 toe = 11.63 MWh).*

***Figure 1.*** *Global energy consumption between 1965 and 2017 [Mtoe/year]*



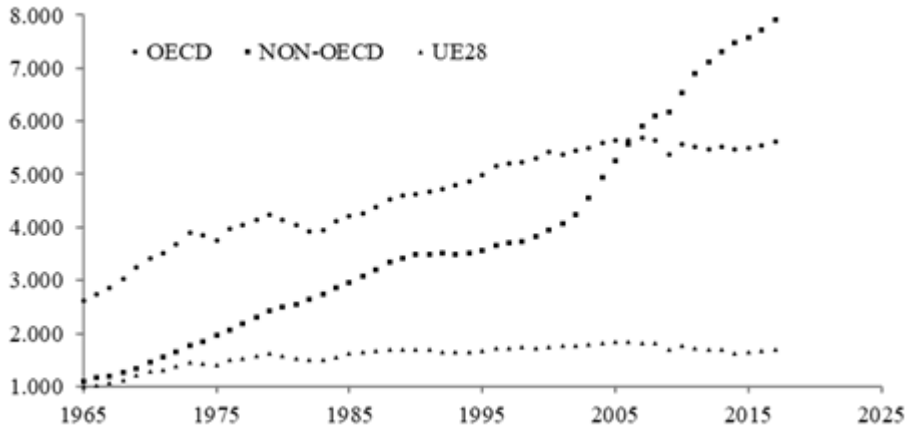

***Source:*** *Authors' own data based on BP Statistical Review of World Energy (2019).*

The melting of ice and permafrost contribute to the increased release of methane to the atmosphere (Ford, 1999; Glikson, 2018). A self-propelling feedback loop - temperature rise - methane emission - gives raise to the rational fear in the science communities (Ripple *et al.,* 2019; Brown, 2001). The humanity armed with advanced technologies and knowledge will take advantage of this phenomena, and through praxeology (Kotarbiński, 1965), kill two birds with one stone - utilize the Arctic methane and save the planet by limiting the release of this greenhouse gas to the atmosphere. In view of the progress in research of methanotrophs - prokaryotes that metabolize methane as their source of carbon and energy - it is within the realms of possibility. Karakurt *et al.* (2011) have noticed that in coal mines, methane oxidation can reduce up to 95% of methane emissions and can be supplemented by energy recovery. This, and the fact that methanotrophs can survive in extreme conditions, not only acidic and hot geothermal fields, is very promising. Their significant role in the ecosystems is also discovered in the Arctic and subarctic lakes rich in methane released from the melting permafrost (Martinez-Cruz *et al.,* 2017).

The humanity will have to face many issues involved in the global warming. There's no denying that the energy issue is a key, strategic issue coming down to a simple question: How to safely shift to renewable, low-emission, less climate-impacting energy sources with the ever-growing energy demand? In this context, an appeal to the humanity was made by thousands of scientists in "BioScience" (Ripple *et al.,* 2019). According to Klingholza, at the beginning of the 21st century, the residents of industrialized countries contributing to just 1/5 of the global population used 2/3 of the global energy (Bertrand, 2002). The industrialization processes expand to more and more countries. Everyone wants to take advantage of limited energy resources - according to the concept of the "tragedy of the commons" developed by Hardin (1968) and systematically recognized by Senge (2012). Since the mid-1960s to the beginning of the 21st century, most of the global energy was consumed by a group

of 36 highly-developed OECD (Organisation for Economic Co-operation and Development) countries. The Pareto principle also seems to apply to this area, since the less developed or non-democratic countries (over 150 countries) for over four decades has been using less energy than the OECD countries. At the turn of the century, the consumption of energy in the non-OECD countries significantly increased, and since 2007, the volume of consumption for this group of countries has been higher than the volume for highly developed countries (Figure 2).

***Figure 2.*** *Energy consumption between 1965 and 2017 [Mtoe/year]*




***Source:*** *Authors' own data based on: BP Statistical Review of World Energy (2019).*

The analysis of the trends in energy consumption shows that Klingholz's views indicating that the trend in energy consumption may be the prime mover of adverse social, economical and environmental changes cannot be denied (Bertrand, 2002). In the long run, no system can continue its growth, either linear or exponential, without major consequences. In "The Limits to Growth", Dennis Meadows proclaims that the perpetual economic growth is impossible on a planet with finite resources. According to Meadows, a sustainable future, as imagined by most people, is impossible, since no steps were taken to change the goals, values and careless approach in the last 40 years despite the well-known limits of the resources.

## 3. Production and Consumption of Energy in the EU Countries

The BP Statistical Review of World Energy report shows that the EU countries use 12.5% of global energy (BP Statistical Review of World Energy, 2019). This share has significantly decreased in the last twenty years and at the end of the 1990s, it was close to 20% of the global energy consumption. In 2017, the EU used approximately 1,700 Mtoe (35 Mtoe less than in 1997). The decreasing energy consumption in the EU was mostly determined by a dynamic increase observed in non-OECD countries. The global energy consumption trends and energy sources

justify Meadows' pessimistic view. Today, as in the 1970s, the energy industry is far from sustainable, since for over 50 years, on a planet with finite resources, the global energy consumption has grown constantly. It can be alarming, since in 2017, just 487 Mtoe was obtained from renewable sources, contributing 3.6% of the global consumption (Table 1).

***Table 1.*** *Energy consumption according to the sources in 2017*

| **Specification** | | **OECD** | **Non-OECD** | **EU** | **Global** |
|---|---|---|---|---|---|
| Oil | Mtoe* | 2 207 | 2 415 | 645 | 4622 |
| | % | 39 | 31 | 38 | 34 |
| Natural gas | Mtoe | 1 442 | 1 713 | 401 | 3 156 |
| | % | 26 | 22 | 24 | 23 |
| Coal | Mtoe | 893 | 2 838 | 234 | 3 731 |
| | % | 16 | 36 | 14 | 28 |
| Nuclear energy | Mtoe | 443 | 154 | 188 | 596 |
| | % | 8 | 2 | 11 | 4 |
| Hydro-electric energy | Mtoe | 315 | 604 | 68 | 919 |
| | % | 6 | 8 | 4 | 7 |
| Renewable energy | Mtoe | 305 | 182 | 152 | 487 |
| | % | 5 | 2 | 9 | 4 |
| Total | Mtoe | 5 605 | 7 906 | 1 689 | 13 511 |

***Source:*** *Authors' own data based on: BP Statistical Review of World Energy (2019).*

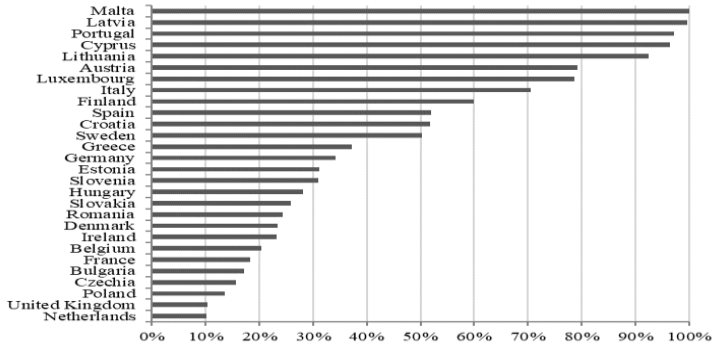
In the OECD countries, the renewable energy covers 5.4% of its annual demand. In the non-OECD countries, using most of the global energy, the renewable sources contribute 2.3% of their overall consumption. In the EU, the contribution is significantly higher at 9%, however, the world still lingers in the age of fossil fuels and non-renewable sources. The energy from coal combustion covers 28%, whereas oil and natural gas cover 57% of the global consumption. Nuclear power engineering (also based on non-renewable resources), hydro-electric and renewable energy sources cover just 15% of the global demand. We can be optimistic about the fact that the society and economy of the 28 European Community countries not only use less energy globally, but more and more energy is obtained from high cost-competitive energy sources, while the fossil fuels are being abandoned. Nuclear, water and renewable sources cover almost 24% of the demand in the EU countries - a good result compared to the global demand (15%) or the non-OECD countries (12%).

Can EU residents feel safe? Can the energy industry in the EU countries be considered sustainable, permanent or at least progressing towards those attributes? To answer those questions, we need to relate to the direction of energy industry transformation in the long run, compare the production and consumption and analyse many factors simultaneously. The analysis should cover not only the issue of primary energy production but also the structure of sources used, in particular, the contribution of renewable energy. The issue of energy dependence is also important,

since at the moment, the imports contribute less than one-third of the energy used in just six EU-28 countries.

Based on the Eurostat statistics, the total energy produced in 2016 in Malta (17,700 Mtoe) was from the renewable sources (Figure 3). No other EU country is close to this result. Malta, as well as Latvia, Portugal, Cyprus and Lithuania can be considered leaders in sustainable development of the energy industry based on renewables. Since in 2016, Malta used 726.1 Mtoe of energy, we can easily deduce that production of own energy covered just 2.5% of the overall demand. The remaining energy was imported (as fossil fuels) making this country one of the most energy dependent from the external sources in the entire EU. Cyprus, also with a high contribution of renewable energy in the primary energy production, ranked second. The most energy independent EU countries in 2016 were Estonia, Denmark, Romania and Poland (Figure 4).

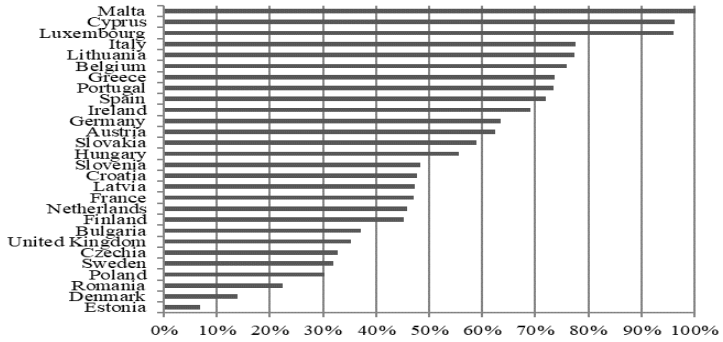
***Figure 3.*** *The contribution of renewable energy in primary energy production in EU-28 countries in 2016 [%]*




***Source:*** *Authors' own data based on:* Energy production and imports (2019).

According to Esperanza Mata Perez, Scholten and Stegen (2019) different EU countries shift to renewable energy at a different rate depending on the politics and divergent interest when dealing with energy security. The authors classify the countries into two clusters. The first cluster include countries protecting the climate and focused on renewable energy (mainly Western European countries). The second cluster includes countries prioritizing supply reliability and preferring the fossil fuels (Central and Eastern European countries). The classification, however, is not obvious. The countries included in the second cluster, due to their geographical location cannot change their energy dependence to the level of the countries included in the first cluster, and the dependence goes hand in hand with renewable production that covers a minor part of the demand. Based on Eurostat 2016 data, the countries that has focused on renewable sources are usually completely or highly dependent on import (Malta, Cyprus, Luxemburg, Italy and Lithuania).

***Figure 4.*** *Energy dependence of EU-28 countries in 2016 r. [%]*



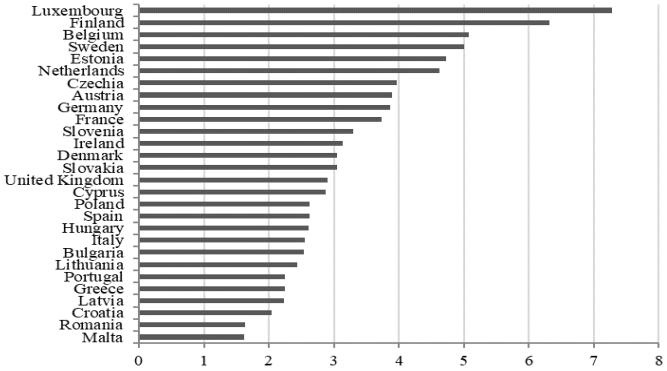

***Source:*** *Authors' own data based on: Energy production and imports (2019).*

Low energy dependence is usually achieved at the price of obtaining most energy from the sources other then renewable (Estonia, Denmark, Romania, Poland, Czech Republic, UK and Bulgaria). The Northern European countries (Sweden, Finland, Latvia) are an exception to the rule, where a relatively large contribution of renewable energy in the production of primary energy comes with a relatively low energy dependence. It should also be noted that the countries obtaining a significant part of the energy from sources other than renewable remain significantly energy independent (Belgium, Greece, Ireland, Slovakia and Germany). Discussing the energy dependence, Högselius and Kaijser (2019) have noted that the smaller European countries are usually more dependent and susceptible at the geopolitical energy market. The energy dependence that can be enjoyed by Germany or Italy is unacceptable for other countries, e.g. Estonia. This pattern does not necessarily apply to smaller countries which due to their surroundings have better possibilities to participate in an international energy trade.

The analysis of the energy sector should also include the issue of per capita energy consumption. In 2016, the average for the European Union was 3.2 toe per capita, with significant differences observed between the countries. In 2016, just 1.6 toe per capita was recorded in Malta, and the value was slightly higher in Romania, whereas, per capita energy consumption in Luxemburg was 7.3 toe, compared to 6 toe for Finland and 5.1 toe for Belgium (Figure 5). At the same time, per capita annual energy consumption for African countries was 0.4 toe, and an average of 1.4 toe/year for South and Central America (BP Statistical Review of World Energy, 2019). However, the annual per capita energy consumption for North America was 5.6 toe. The rates for Luxembourg and Finland seems high, however, they are nowhere close to the world's biggest users including: Qatar (18.5 toe per capita), Singapore (14.9 toe per capita) or the United Arab Emirates (12 toe per capita). The examples show a serious issue of the modern world - an intragenerational justice (Domański, 1997), and this notwithstanding that with the growing wealth of the society, the pressure on the environment rises and according to Żylicz (2004) only the high levels of wealth will allow the trend to be suppressed or reversed in

accordance with the Kuznets curve, in some of the aspects (e.g. water and air pollution, and waste treatment). This is further verified by the research conducted by Wawrzyniak (2018). The author reports that in the EU, between 1990-2013, the relation between the emission of $CO_2$ and per capita GBP was in the shape of a reversed letter "U".

***Figure 5.*** *Energy consumption in the EU-28 countries in 2016 [toe/per capita]*



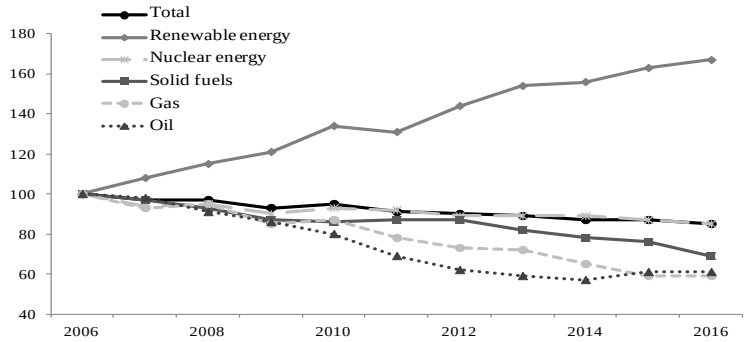

***Source:*** *Authors' own data based on: Energy production and imports (2019).*

Analysis of the values and the structure of energy production in the EU-28 countries should not only allow for the sources used to produce the energy but also how much the volume of the production meets that demand of the EU-28 countries. The study shows that for over a decade the production of own energy doesn't cover even half of the demand of the EU countries. The energy dependence rate has been maintained for the entire European Community at a similar level of 45%. What's more, the production of primary energy in the analysed timeframe shows a downward trend, i.e. in 2016 it fell by 15% compared to 2006. Manteuffel Szoege (2005) reminds us about the shock felt around the world in the 1970s as a result of two major energy crises due to the cartelisation of the majority of oil exporters. Twice, the Organization of the Petroleum Exporting Countries (OPEC) has successfully (in 1973 and 1978) forced the global market to greatly increase the prices by drastically limiting the extraction and sales of oil. Still, in the modern world, we can observe political phenomena of influence and blackmail, in particular, in situations when the exporter becomes a monopoly or an oligopoly, and not only takes control over the volume of the energy resources but also their prices. The pressure was felt throughout the years by most Eastern European countries. Since 2004, Russia has stopped the natural gas supplies to Poland seven times.

The analysis of the period between 2006 and 2016 shows that the dynamic of the production of primary energy in the EU countries follows a downward trend. This applies to four major sources: natural gas (by 41%), oil (by 39%), solid fuels (by 31%) and nuclear energy (by 15%). The decrease was compensated by a significant, however, insufficient to fully substitute for, increase in production of energy from

renewable sources (by 67%). The volume of the total energy produced by the EU countries is getting smaller by the year (Figure 6). In the absolute approach, in 2016, the production of primary energy in the EU-28 countries was 755 Mtoe (approx. 45% of the total consumption), whereas, 10 years before, the production was almost 885 Mtoe (approx. 48% of the total consumption).

***Figure 6.*** *The dynamic of primary energy production in the EU-28 countries in 2006-2016 [%]*




***Source:*** *Authors' own data based on: Energy production and imports (2019).*

In 2016, the highest production of primary energy among the EU countries was recorded in France (17.3% of the total EU-28 production), followed by the UK (15.8%) and Germany (15.3%). Within the structure of primary energy production in the EU-28 countries, nuclear energy has the highest share at 28.7% and its significance is the highest in France, where it contributes 80% of the national production of primary energy. In Belgium, it contributes three-quarters and in Slovakia - over three-fifths of the produced volume.

The nuclear energy is still considered a modern, clean and competitive source of energy. It should be noted that the developed world that has been using the nuclear energy for the last several decades, is gradually abandoning it. The German government plans to shut down all its nuclear reactors by 2022 (Energy production and imports, 2019). The French government has similar plans for the nearest decade. In 2018, president Macron has announced shutting down 14 out of 58 of the reactors by 2035. France is planning to reduce its share of nuclear energy to 50% and focus on the development of renewable sources.

Many EU countries are almost completely dependent on the import of primary energy. That trend is not optimistic, since during the analysed decade five countries has significantly increased their energy dependence, e.g. Denmark, the UK, Lithuania, the Netherlands and Poland. In other countries, the reduction in production of primary energy due to the depletion of resources was compensated by increasing the imports. This relationship, however, to a smaller degree, was also observed in Belgium, Czech Republic, Greece, Germany and Malta. In other EU

membership countries, the energy dependence rate fell between 2006 and 2016. Estonia is an interesting example where the energy dependence fell from 29.2% to 6.8%. The rates also fell significantly, by approximately 10%, in Ireland, Latvia, Portugal and Austria. We should also consider the fact that those countries are relatively small and the fall in import dependence did not significantly affect the overall energy dependence of the European Community.

The presented statistics show that the issue of security and sustainability of the energy sector of the EU-28 countries is highly complex. The EU countries are interlinked with a dense network of energy and gas relations. The membership countries are focused on their own particular interests and agendas, and in their relations with the third countries they represent different approaches, often being the opposite parties in their relations with the suppliers of energy carriers which, at the oligopolistic energy market, often put them in an awkward position. Even though Europe gradually reduces the use of fossil fuels in production of energy, it still uses them. It has simply changed its status from a global (continental) point of view from a major producer to a major importer which does not significantly reduce the volume of non-renewable energy on a global scale.

## 4. Conclusions

The European Community countries use different energy system approaches. The countries using the most renewable sources in production of their own energy (i.e. Malta, Cyprus, Lithuania or Portugal) are highly energy dependent due to the shortages in a balance between energy production and consumption of at least 75%. Economies risk a lot due to their dependence on imports of, incidentally, fossil fuels. A relatively small fraction of energy comes from renewable sources (less than one-third of energy produced) in countries with a high energy independence ratio, including Estonia, Denmark, Romania and Poland. This independence is achieved at the price of a large contribution of fossil fuels, that is coal in case of Poland.

A key aspect of the analysis of the energy sector is the energy consumption per capita and its environmental consequences. In the last decade, per capita consumption fell by 13% in the EU-28 countries, although, it is still at an average level of 3.22 toe/year. For the last several decades, Europe continues the risky process of growing energy dependence, in particular, from Russian suppliers. The vast majority of EU-28 countries is almost completely dependent on the imports of energy carriers and consumes huge amounts of energy without covering even half of the demand, bearing the risks arising from external supplies.

The energy imbalance without an energy deficit is a serious threat to the development of smaller countries and those countries whose geographical location make it difficult to diversify the supplies by participating in an international energy trade. It’s no wonder that those countries prefer the exploitation and consumption of their own fossil fuel resources. Notwithstanding, the direction of further

development of power engineering in the European Community for the nearest decade is clear. The future will be determined by the renewable sources and gas fuels. The study shows that the issue of balancing the consumption and production of energy in a short-term perspective seems to be in opposition to the issue of diversification and renewability of the energy sources.

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