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Power generation in the European Union and in Poland in the context of sustainable development

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Abstract

Motivation: The concept of sustained development has been implemented on an increasingly large number of areas of human activity. Energy is one of those areas in the European Union in which this idea is used.

Aim: The aim of this study is to assess the energy generation development in Poland and in the other EU countries in the context of sustainable development policy.

Results: Considering the highly diverse environmental circumstances, not all countries are likely to meet the ambitious objectives of the EU energy policy in the area of environmental conservation without having to make sacrifices in the socio-economic area. Taking into account the EU's enormous dependence on external supplies of energy carriers, it seems justified to use the concept of sustainable energy security, taking into account the social and technical conditions of individual countries.

Keywords: energy generation; sustainable development; sustainable energy; European Union; energy carriers; RES
JEL: Q01; P48; Q42; K32; O13; P13

1. Introduction

The idea of sustainable development was first presented internationally in the 1987 Brundtland report (World Commission on Environment and Development, 1987). In this report, sustainable development is defined as a process

that meets the needs of the contemporary generation without compromising the opportunities of future generations to exist at a similar level. Therefore, such an approach requires adjustment of strategies for the development of national economies in which political, economic and social activities are fully integrated while maintaining the natural balance (Bilan et al., 2019; Semenenko et al., 2019; Vasylieva et al., 2019). The practical implementation of the principles of sustainable development involves changes in all areas of human activity. In particular, it requires efficient use of energy resources so that future human existence is not threatened by lack of access to energy sources (Boyle at al., 2004; Czech, 2016; Mitchell, 2010; Shindina et al., 2018).

Access to energy resources has a huge impact on the processes taking place in the socio-economic space and, as history shows, natural resource extraction and trading very often cause regional conflicts (Belyi, 2015; Maltby, 2013; Müller-Kraenner, 2009). These circumstances and the irreversibly imminent exhaustion of conventional fuels have forced the international community to set out a new global development path, in which the energy industry will be of paramount importance (Adamkiewicz, 2017). The concept of sustainable energy, like the term 'sustainable development', is based on three pillars: sustainable economic development, environmental protection and meeting social needs (scheme 1) (Balcerzak & Pietrzak, 2017; Pietrzak et al., 2017).

One of the most important problems in the area of sustainable social and economic development of the EU is its very high dependence on imports of energy carriers. This issue is of particular importance for the countries of Central and Eastern Europe, in particular for Poland, not only for geopolitical reasons, but also in the context of long-term economic stability (Czech, 2017; Semenenko, 2016; Stavytskyy et al., 2018). The share of imported raw materials in the consumption of primary energy in the EU increased from 46.7% in 2000 to 53.6% in 2016; however, this ratio increased from 75.7% to 86.7% for crude oil and petroleum products, from 48.8% to 70.4% for gas and from 30.6% to 40.2% for solid fuels. A comparison of the EU share (5.5%) in global primary energy production with the EU share (11.6%) in global final energy consumption indicates a huge energy dependence of the EU (chart 1). This dependence on external sources of energy resources largely explains the EU's commitment to the practical implementation of the Sustainable Energy objectives. It manifests itself mainly by striving to increase the energy efficiency of macro-sectors of the EU member states economies and increasing the use of renewable energy sources.

The European Union adopted an energy and climate package in 2007 (the so-called '3x20'), which imposed on members states an obligation to achieve specific quantitative goals, including greenhouse gas emissions and energy production from renewable sources (RES) (Kasperowicz et al., 2017). The goals to be achieved by 2020 concern the following issues:

– greenhouse gas emission reduction by 20% as compared to the reference year 1990;

– increasing the share of energy from renewable sources to 20%;
– reduction of primary energy consumption by 20% by 2020 compared to the EC forecasts for 2020.

The last objective is optional for individual countries; however, in October 2014, the European Council set an objective of a 27% improvement in energy efficiency in 2030, while emphasising the possibility of increasing the objective to 30%. It should also be borne in mind that the problem of increasing energy efficiency based on the concept of sustainable energy development is included in the key long-term European Union development strategy — the Europe 2020 plan, the implementation of which is mandatory at the Member States level (Balcerzak, 2015).

Considering the above, the aim of the article is to assess the development of energy in EU countries in the context of the sustainable development policy proposed by the EU.

The following hypothesis was verified: energy industry development in individual EU countries is not in line with the sustainable development policy. In this context, a research question arises: are the actual effects of EU energy policy and its 2020–2030 objectives compatible with the three pillars of sustainable development?

2. Methods

The research problem and objective were decisive factors in choosing the study methodology. In order to achieve the study objective, a comparative qualitative analysis was performed, using macroeconomic data provided by Eurostat (2018). European Union member states, especially Poland, were taken as the study area. A comparative analysis of Poland and selected EU countries was carried out using descriptive statistics and a time series analysis (examining the structure and dynamics).

3. Results

3.1. Analysis of the situation of the European Union in terms of energy

The consumption of final energy increased by 33% during the 2000–2016 period, reaching 9,384 Mtoe. During this period, China recorded the largest increase in final energy consumption (by 142%), while energy consumption in the EU decreased by 6%. A slight upward trend in energy consumption took place during the period preceding the introduction of the energy package (annual average of approx. 0.5%), and the consumption decreased after 2007 by 0.8% on average year-on-year. Poland was one of the few EU countries where energy consumption was gradually increasing. Since the beginning of the century, con-

sumption of final energy has increased by 20.8%, with the highest growth rate observed in the years 2000–2007 (by 11.6%). The increase in the demand for energy in Poland was a result of economic growth, which is a natural economic phenomenon in developing countries. The value of Poland's energy efficiency index[1] increased in 2016 by over 89% compared to 2000, while for all EU countries taken together it increased by 67.6%. However, Poland's energy efficiency still accounts for only 48% of the EU average energy productivity.

Differences are also visible in the structure of gross energy consumption in Poland in relation to the structure in the EU–28 (charts 2 and 3). Solid fuels were the dominant energy carrier in Poland during the period of 1995–2016, particularly hard coal, with a 44.4% share in the domestic consumption in 2016. Its share decreased by almost 19 percentage points compared to 1995; however, it is still the dominant fuel in Poland. Increasing the consumption of energy from RES is a positive trend from the point of view of sustainable development principles; in 2016, it accounted for 9.2% of gross energy consumption (chart 3). For comparison, the share of RES in the EU gross energy consumption amounted to 13.2%, while hard coal accounted only for 9.7% of energy sources.

A comparison of the share of selected countries in the consumption of a given energy carrier in the EU–28 with the share of this country in the total gross energy consumption of the EU–28 allows to assess how much the national economy relies on a given energy source. This relationship is illustrated in chart 4, in which selected EU countries are presented on a heptagon. The vertices symbolise energy carriers and the distance from the central point reflects their importance in national energy systems. The analysis of the consumption profile of energy carriers in Poland indicates a gradually decreasing importance of hard coal as an energy source. However, the position of crude oil, natural gas and RES in the structure of consumption of the most important energy sources has increased over the last two decades. Among the analysed countries, Germany has the most diverse consumption profile in the most important groups of energy carriers. In turn, the atom is the main energy source in France — nuclear power plants produce 75% of energy in this country (chart 4).

Observation of the final energy consumption evolution in the EU between 1995 and 2016 reveals opposite trends in consumption levels in individual sectors. The final energy demand in the agriculture and forestry sector decreased during this period by 21.5% and in industry — by 16.5%. A significant increase in energy consumption was observed in the service sector (by 31.2%) and in transport (by 19.1%). Transport (33.2%), followed by industry (25.7%) and individual customers (25.7%) the largest share in the final energy consumption in the EU–28 in 2016 (chart 5). These trends reflect mainly the structural changes in the EU economy, i.e. departing from energy-intensive economies and the increasing share of services.

[1] The efficiency index was calculated as a ratio of the annual GDP volume to the amount of final energy consumed.

Fundamental changes in energy consumption in particular macro-sectors also took place in Poland during the analysed period. First, the final energy consumption in the transport sector more than doubled (by 131.8%); in 2016 it accounted for 28.9% of the total final energy consumption in Poland. The demand for energy in the service sector increased at a similar rate as the EU average (by 14.2%), and it decreased in industry by 32.2% (chart 6).

The analysis of final energy consumption in particular sectors is summarised in a synthetic comparison of energy consumption profiles in selected EU countries, i.e. Poland, the Czech Republic, Germany and France. Each vertex of the hexagon symbolizes a specific macro-sector: industry, transport, households, services, agriculture and others.

The proportions of final energy consumption by different sectors in the analysed countries are different. In the case of Poland and the Czech Republic, households are the largest energy consumers and it is in this sector that the greatest potential for reducing energy consumption lies. Compared to other countries, Polish agriculture should be classified as the most energy-intensive sectors despite a 30% reduction in energy consumption (chart 7) (Borozan, 2018).

3.2. Energy efficiency in EU countries

Energy efficiency is considered one of the three strategic energy policy objectives in the EU. The productivity of energy consumption in an economy is a key factor in the cost of doing business and in the social cost of living. The energy intensity of the national economy can be measured as the ratio of the consumption of both primary and final energy to the corresponding production volume (measured by GDP) (Kasman & Duman, 2015).

The energy intensity of the Polish economy is currently estimated at twice as high as the European average (chart 8). However, the final energy intensity of Poland's GDP has decreased almost by the factor of four over the last two decades. In 1995, it amounted to 909 kgoe/1000 euro, while in 2016 it was 234 kgoe/1000 euro. Positive trends in the effectiveness of energy use in Poland are also confirmed by changes in the efficiency indicators during the 1995–2016 period. The gross energy efficiency of Polish GDP, expressed in constant 2010 prices, amounted to 4.3 euro/kgoe in 2016 and it was higher by 126% than in 1995 (1.9 euro/kgoe). If purchasing power parity is taken into account, Poland's energy efficiency during the analysed period increased by 208%, while the rate of this efficiency improvement was more than twice as high as in the European Union (chart 9).

The Energy Efficiency Directive (EED, 2012) requires EU member states to set national goals for energy efficiency (Shogenova et al., 2014). These targets can be expressed in terms of primary or secondary energy. Chart 10 shows the degree of implementation of the primary and secondary energy reduction plan compared to the planned level of primary and secondary energy consumption in 2020 in individual EU countries. In 2016, 16 EU member states — in-

cluding Poland — achieved lower final energy consumption than the 2020 target. Similarly, 17 member states reported lower primary energy consumption than the 2020 target in 2016 (chart 10).

Other EU countries are still achieving higher energy consumption than their 2020 targets. However, it should be noted that EU countries have set more or less ambitious targets for themselves (European Commission, 2015). For example, Croatia, Cyprus, Finland, Greece, Italy, Italy, Portugal and Romania have set targets at levels that even allow for an increase in final energy consumption. The fact that the sum of national primary energy consumption targets only leads to a 17.6% reduction in consumption, while the EU-wide target is 20%, also shows the different levels of ambition in reducing national energy consumption (European Commission, 2017).

3.3. Share of energy from renewable sources

Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (2009) has been in force for almost 11 years. By 2020 20% of the final energy consumed in the EU as a whole is to be obtained from renewable sources, with different target percentages being assigned to individual member states. These targets have been set at such a level that, on the one hand, they are realistically achievable while, on the other, they motivate individual countries to increase the share of RES (Scarlat et al., 2015).

In 2016, in total, the EU–28 had a 17% share of RES in final energy consumption, and out of 28 countries, 11 exceeded their target levels. The countries with the greatest backlog: France — 7% to achieve 23 pp, The Netherlands 8% and the UK 5.7%. Poland with its 3.7% deficit can be included in the group of countries which can realistically achieve the 2020 goal of 20% of the share of RES (chart 11).

The structure of energy from renewable sources (by source) in the EU–28 and Poland in the years 2005–2016 is presented in charts 12 and 13. The structure of energy generation from renewable sources in Poland (chart 13) differs significantly from the structure of renewable energy sources in the EU–28. This structure, like in other countries, results primarily from the geographical conditions characteristic for Poland and the resources that can be utilised.

Solid biofuel was the dominant source of renewable energy in the EU–28 from 2005–2016, with a share gradually decreasing to reach 44.7% in 2016. Conversely, the share of solar energy (solar thermal energy systems plus photovoltaic systems) increased from 0.7% to 6.3%, wind energy — from 5.0% to 12.4% and biogas — from 3.4% to 7.9% (chart 13).

Solid biofuels had a dominant position in domestic energy generation from renewable sources. Their share in obtaining energy from RES in 2005 was as high as 91.6% and in the following periods, this share gradually decreased in favour of other renewable energy sources. In the period in question (2005–2016), the share of wind energy increased from 0.3% to 12%, solar energy from almost

zero to 0.7%, liquid biofuels (bioethanol plus biodiesel) from 2.6% to 10.2%. In absolute terms, the highest increase in the consumption of energy from renewable sources was recorded in wind energy. In 2005, a system of financial support for renewable energy was launched in Poland. As a result, the so-called 'wind turbine boom' began and the capacity of wind farms in Poland in the years 2005–2016 increased from 83 to 5,800 MW. Therefore, wind energy became the second, in terms of share, renewable energy source (chart 13).

A comparison of RES energy consumption profiles for Poland and selected EU countries (Germany, France, Czech Republic) shows the flaws of adjusting the structure of RES production and consumption in Poland to the existing natural and economic conditions, which also shows the weaknesses of the state policy in terms of supporting the development of renewable energy (Neck, 2016). In western countries, biogas production is being intensively developed, which in many EU countries is more efficient than other renewable energy sources such as wind or solar energy (Scarlat et al., 2018). It is also noteworthy that the application of relatively new solar energy technology, i.e. photovoltaics (see more in Sampaio & Gonzalez (2017)), is increasing rapidly in EU countries. Until now, both RES have a small share in Poland's energy consumption (chart 14).

Consumption of energy from renewable sources in individual sectors is another important issue apart from the overall RES consumption balance. Chart 15 shows the share of RES in three sectors between 2004 and 2016.

Over the analysed 22 years, the share of RES has been growing in all the sectors under consideration; however, the largest scale of the use of this energy is in the heat-engineering sector. In Sweden, for example, almost 70% of heat is generated from renewable sources and more than 65% of electricity is generated from renewable sources. Similarly, in Poland, although on a much smaller scale, renewable energy is used mainly in electricity generation and in heating. To a relatively small extent, renewable energy sources are used in transport, where traditional energy sources dominate. For this reason and due to the expected increase in the share of this sector in generation of the GDP, increasing the use of RES in powering means of transport will be one of the biggest challenges to the EU (chart 15).

3.4. Reducing greenhouse gas emission

The third assumption of the EU energy policy is to reduce greenhouse gas emissions by 20% compared to 1990. The following countries met the objectives of the EU energy policy with regard to greenhouse gas emissions in 2016: Lithuania, Latvia, Romania, Estonia, Slovakia, Bulgaria, the United Kingdom, the Czech Republic, Hungary, Denmark, Germany, Sweden and Croatia (chart 16). In the same year, the total amount of greenhouse gas emissions in all 28 member states amounted to 77.64% of the 1990 emission level. Among the countries that had not yet met the target level of gas emissions was Poland,

which was still more than 5 percentage points behind in limiting the emission of harmful gases to the atmosphere.

Poland is also in the group of countries where greenhouse gas emissions expressed in tonnes per capita are higher than this index for the whole EU–28. In 2016, it was even higher (10.5 tonnes per capita) compared to the year 2000, when Poland emitted 10.2 tonnes of greenhouse gases per capita (chart 17).

3.5. Energy security in the EU

Energy security is becoming increasingly important today, especially among EU Member States. It is one of the most important aspects of the economic and international security of individual countries and, consequently, of the EU as a whole. Energy security is a multi-faceted concept that is difficult to define unambiguously, especially when considered from the point of view of national interests. The perception of energy independence as the availability of different energy sources and ensuring the continuity of their supply is not sufficient in today's conditions. Due to the diversification of raw materials supply sources and the use of own resources, efficient use of energy and environmental protection is the key to energy security. The price level, which should be acceptable to consumers, is also an integral part of this security (Szymczyk, 2011).

The demand for EU primary energy in 2016 was 53.6% met by the import of energy carriers. When analysing the structure of primary energy consumption in the EU, an increase in the share of imports of crude oil, petroleum products and natural gas is noticeable. The ratio for crude oil increased from 75.7% in 2000 to 86.7% in 2016, while the share of gas in the corresponding period increased from 48.8% to 70.4%. In the case of solid fuels, the level of covering EU demand with own extraction is approximately 59.8%, while the rest of the demand is satisfied by imports. Poland is one of the few EU countries with a relatively low share of energy resource imports, mainly as a result of a large share of its own solid fuels in primary energy consumption.

4. Conclusion

The EU energy policy 2020 objectives are likely to be achieved — if not by all Member States — at a Europe-wide level. However, the new EU energy policy 2030 objectives appear to be over-ambitious and rather difficult to achieve. The climate and energy policy framework for 2020–2030 includes the following objectives (Eropean Commission, 2014):

- reduction of greenhouse gas emissions by 2030 by at least 40% compared to the 1990 levels;
- increase the share of renewable energy in the EU's energy consumption to at least 27%;
- improvement in energy efficiency in 2030 compared to projections — an indicative target of at least 27%.

Achieving these objectives will require greater involvement of the European Union Member States in environmental issues than has been the case to date. Their achievement will involve a heavy financial burden, which may have a negative impact on social and economic development. Such a situation would be contrary to the principles of sustainable development. In addition, some countries, including Poland, may have particular difficulties in meeting the EU's energy policy objectives.

An analysis of the research results from the point of view of the hypothesis indicates that the energy industry in many EU countries (including Poland) is not developing in accordance with the assumptions of sustainable development.

In this case, it seems appropriate to use the new concept of sustainable energy security, taking into account the social-technical-economic conditions of individual EU countries. After all, not every country has favourable environmental conditions in the context of the sustainable development policy, e.g. Sweden and Denmark can develop their energy system only on the basis of renewable sources. For Poland, such a solution is too expensive for the time being, because only a postulate of decarbonisation would lead to an increase in energy prices and a decrease in the international competitiveness of the Polish economy. Therefore, this concept would integrate the areas of sustainable development with security within the energy policy of a country. The most important postulates of this concept should include (Adamkiewicz, 2011):

– rationalisation of the energy system based on the available (domestically) conventional and unconventional resources;
– developing citizens' awareness of energy-related issues;
– regionalisation and dispersion of energy generation.

In the case of Poland, the implementation of the first postulate would be based mainly on hard coal and brown coal resources. Over time, these sources would be replaced by other energy sources, mainly by RES, but with the simultaneous fulfilment of the condition of energy independence of the economy. The postulate of a high level of energy-related awareness in the population is a kind of catalyst for the implementation of the third postulate, i.e. the development of a dispersed power system. Only when the needs and opinions of local communities are taken into account, will entrepreneurs invest in individual energy generation. Germany is a good example of such a dispersed power generation model, where local energy cooperatives produce energy for their own needs based on local resources (e.g. biogas in agricultural regions). Naturally, such a system must work with a large power plant as a stabiliser of sustainable energy (Adamkiewicz, 2011).

One way to increase energy efficiency is to use the latest technologies, such as alternative fuels and vehicle drive technologies. Transport, alongside households, is the sector with the greatest potential for increasing energy efficiency. The electric drive powered by hydrogen fuel cells seems to be a particularly promising technology, considering the fact that hydrogen is produced in Poland as a by-product. The food and chemical industry in Poland produces about one

million tonnes of hydrogen, which could become one of the most 'clean' energy carriers. The EU is intensively promoting electrification of means of transport as a way of reducing emissions of hazardous compounds into the atmosphere. However, it must be noted that electricity must first be produced by power stations, often from conventional energy sources, and then stored in batteries. These, in turn, are very inefficient energy storage facilities and make electric cars no more environmentally friendly than conventionally powered ones. It is, therefore, necessary to anticipate that the hybrid and electric vehicle drive technologies currently in use are temporary solutions. In the author's opinion, e.g. the development of charging infrastructure for electric cars in the context of sustainable development postulates raises considerable doubts. Fuel cell technology (FCEV), especially in Poland, is much more in line with the concept of sustainable energy.

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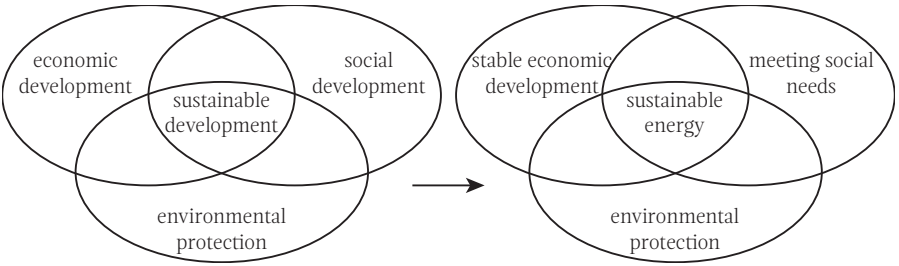
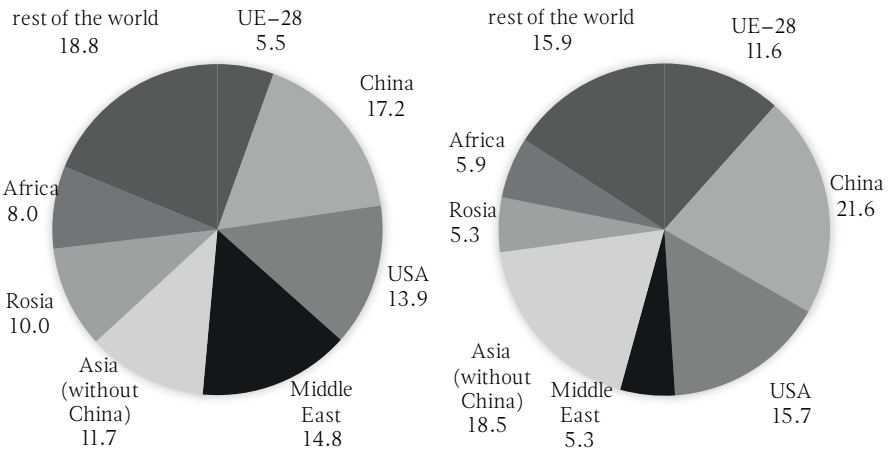
Appendix

Scheme 1.
The idea of sustainable development and a concept of sustainable energy



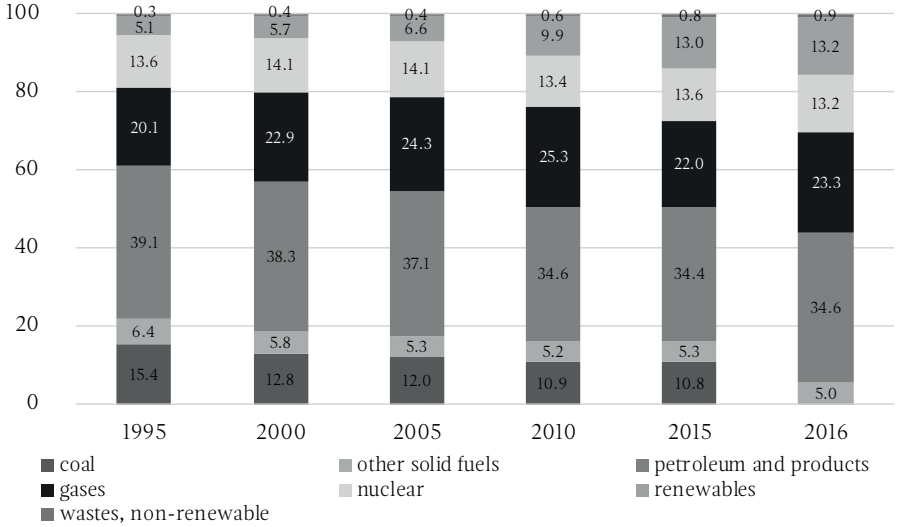
Source: Own preparation.

Chart 1.
Global structure of energy production (on the left) and consumption (on the right) in 2016 (in %)



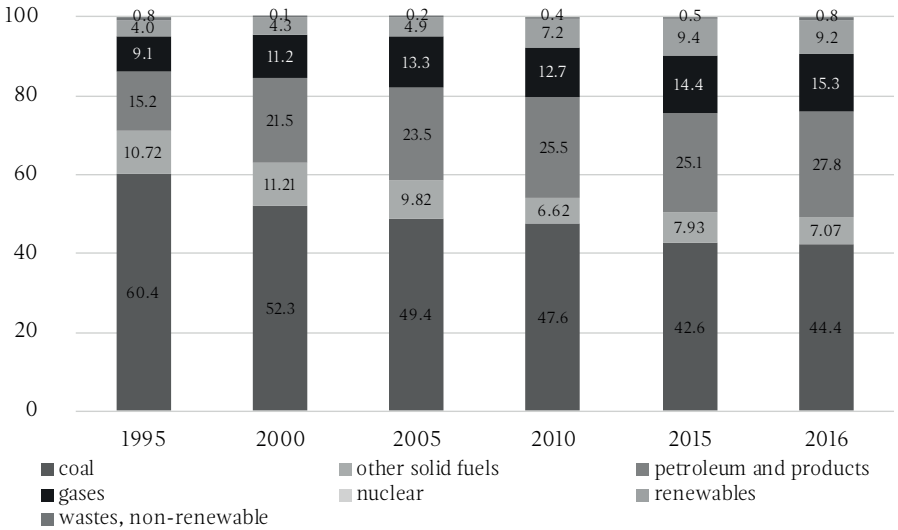
Source: Own preparation based on European Commission (2018).

Chart 2.
Share of different energy carriers in gross energy consumption in the EU–28 in 1995–2016 (in %)



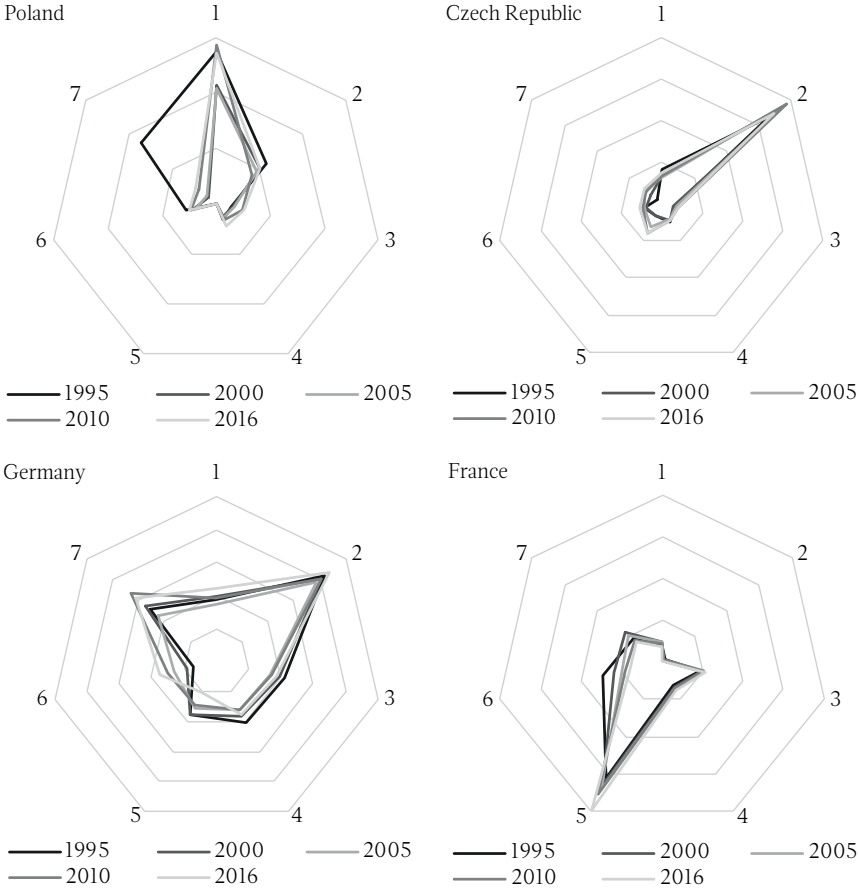
Source: Own preparation based on Eurostat (2018).

Chart 3.
Share of different energy carriers in gross energy consumption in Poland in 1995–2016 (in %)



Source: Own preparation based on Eurostat (2018).

Chart 4.
Graphical presentation of energy carrier consumption profiles in selected EU countries in 1995–2016

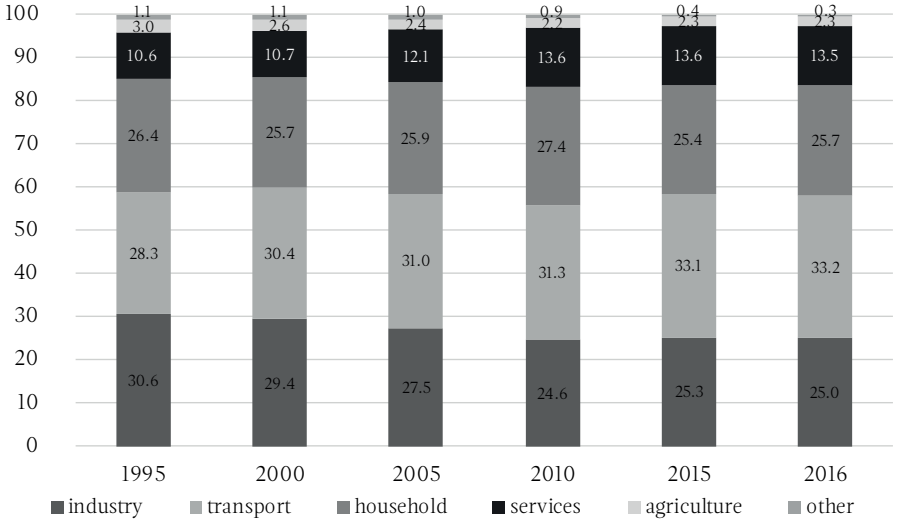


Notes:

1 — coal; 2 — other solid fuels; 3 — petroleum and products; 4 — gases; 5 — nuclear; 6 — renewables; 7 — wastes, non-renewable.

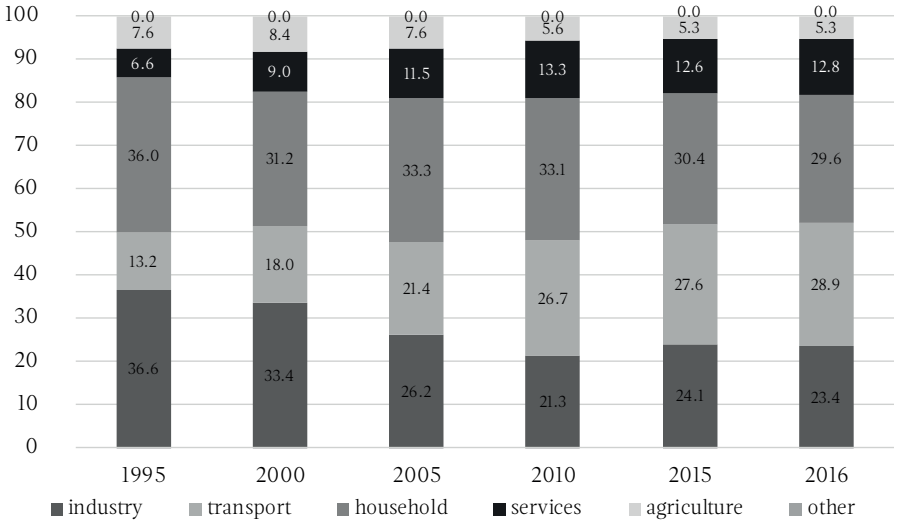
Source: Own preparation based on Eurostat (2018).

Chart 5.
Structure of final energy consumption by sector in the EU–28 in 1995–2016 (in %)



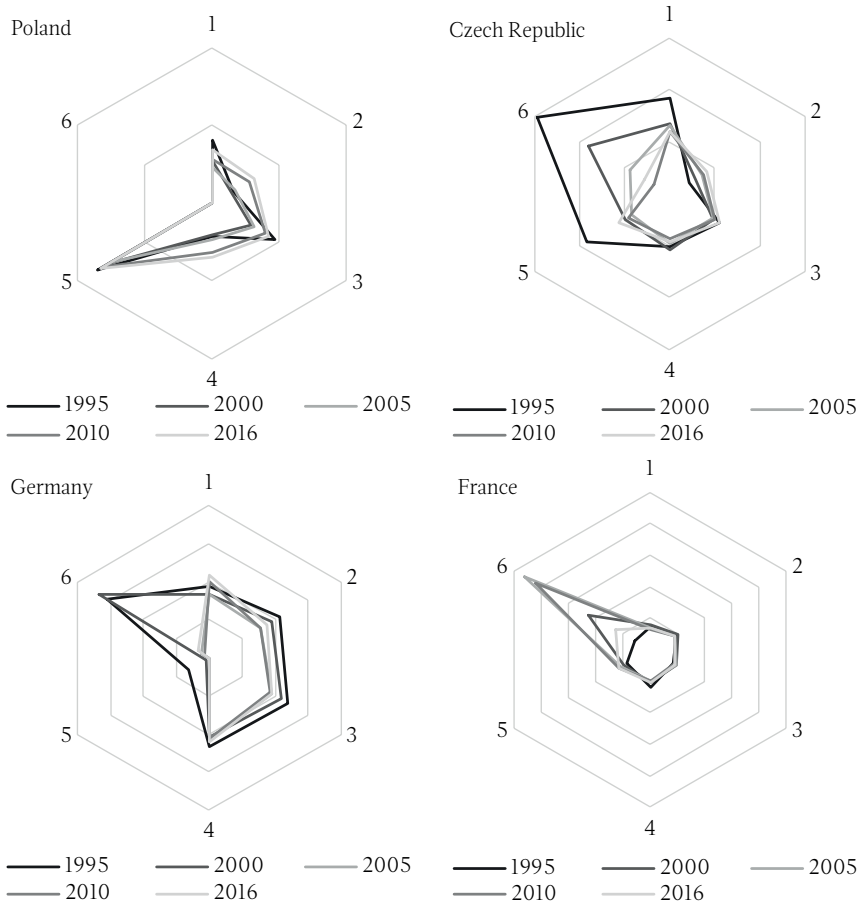
Source: Own preparation based on Eurostat (2018).

Chart 6.
Structure of final energy consumption by sector in Poland in 1995–2016 (in %)



Source: Own preparation based on Eurostat (2018).

Chart 7.
Graphical presentation of energy carrier consumption profiles in selected EU countries in 1995–2016

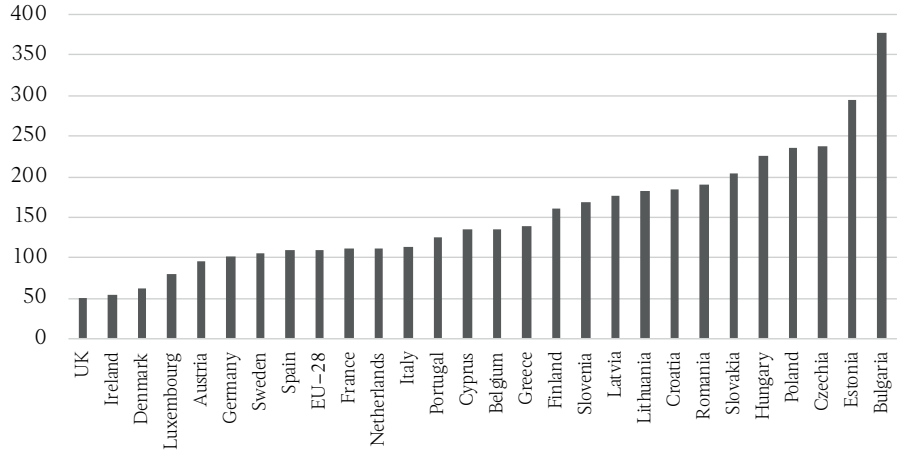


Notes:

1 — industry; 2 — transport; 3 — household; 4 — services; 5 — agriculture; 6 — other.

Source: Own preparation based on Eurostat (2018).

Chart 8.
Final GDP energy intensity of the EU national economies in 2016 (in kg oe/1000 EUR)

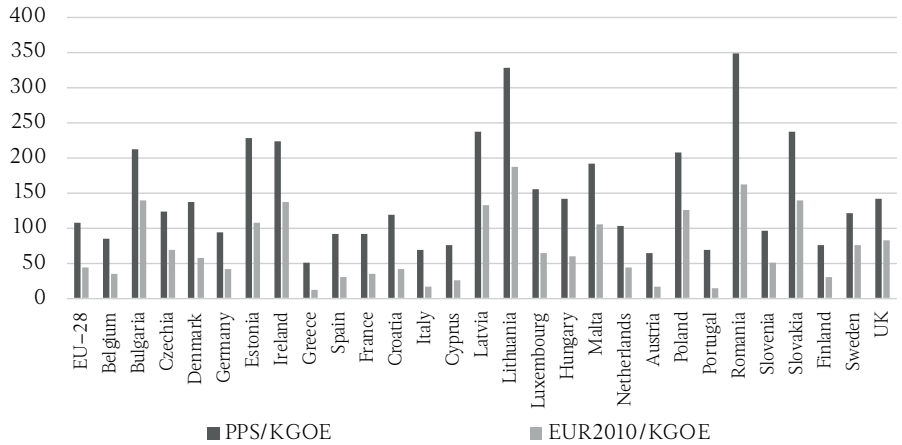


Notes:

Energy intensity of the economy expressed as the ratio of energy consumption to GDP (in market prices).

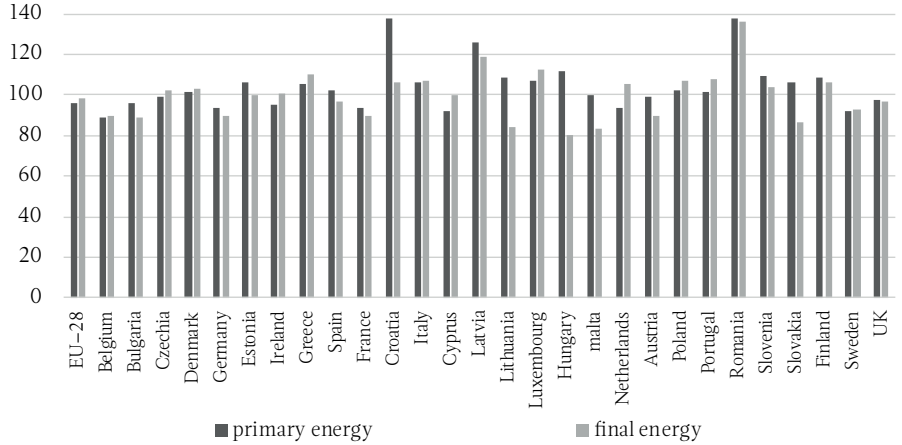
Source: Own preparation based on Eurostat (2018).

Chart 9.
Changes in energy efficiency in EU countries in 1995–2016 (in %)



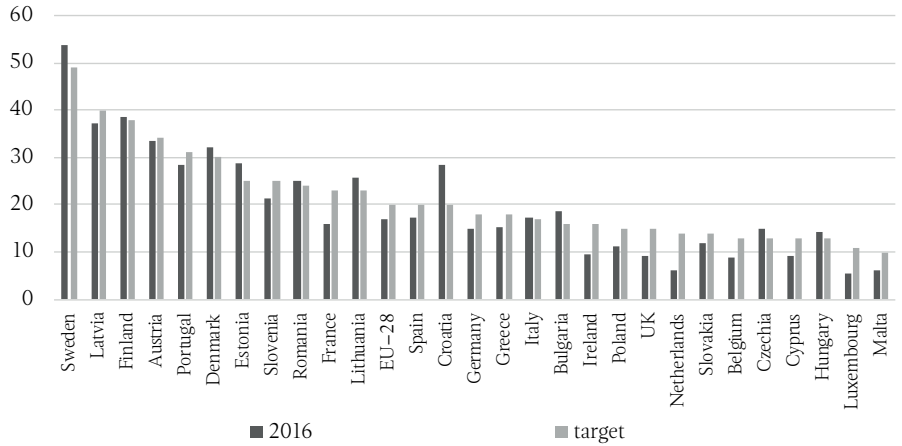
Source: Own preparation based on Eurostat (2018).

Chart 10.
Progress of accomplishing the national primary and final energy consumption reduction targets: state for 2016 (in %)



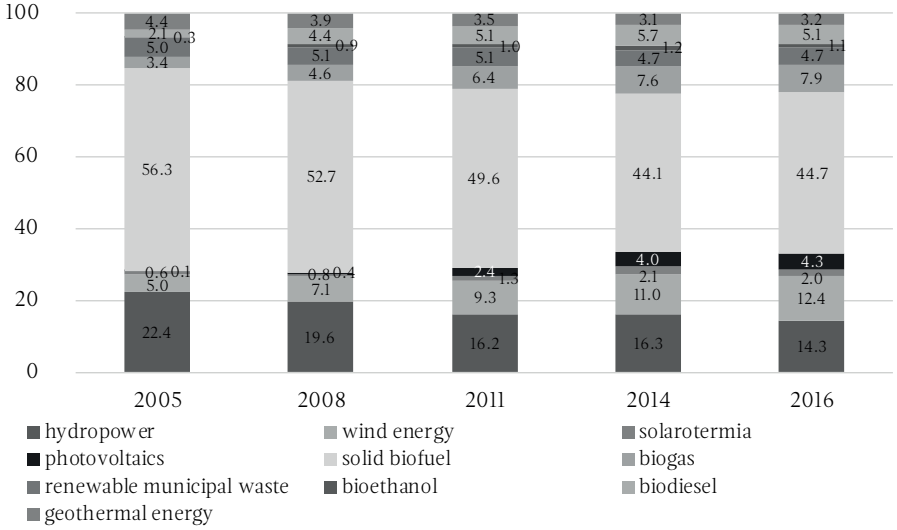
Source: Own preparation based on Eurostat (2018).

Chart 11.
Share of RES in the EU–28 countries in 2016 (in %)



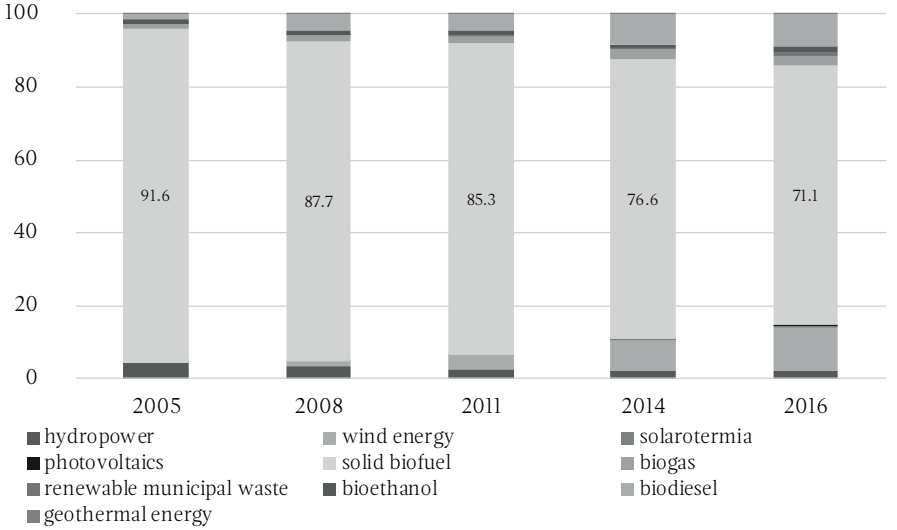
Source: Own preparation based on Eurostat (2018).

Chart 12.
Structure of RES acquisition by carrier in the EU–28 during the 2005–2016 period (in %)



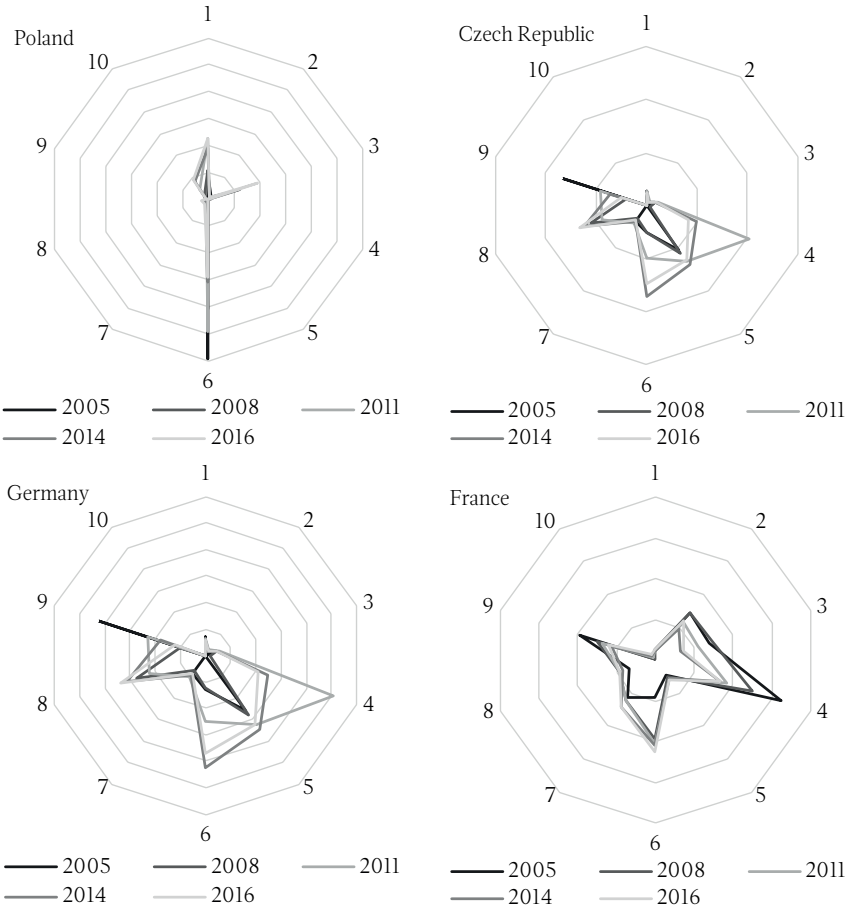
Source: Own preparation based on Eurostat (2018).

Chart 13.
Structure of RES acquisition by carrier in Poland during the 2005–2016 period (in %)



Source: Own preparation based on Eurostat (2018).

Chart 14.
Graphical presentation of RES consumption profiles in selected EU countries in 1995–2016

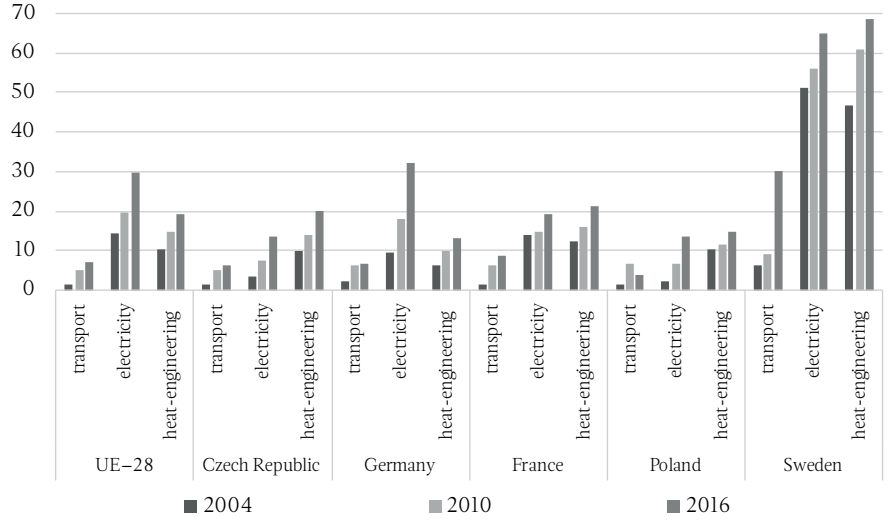


Notes:

1 — hydropower; 2 — wind energy; 3 — solarotermia; 4 — photovoltaics; 5 — solid biofuel; 6 — biogas; 7 — renewable municipal waste; 8 — bioethanol; 9 — biodiesel; 10 — geothermal energy.

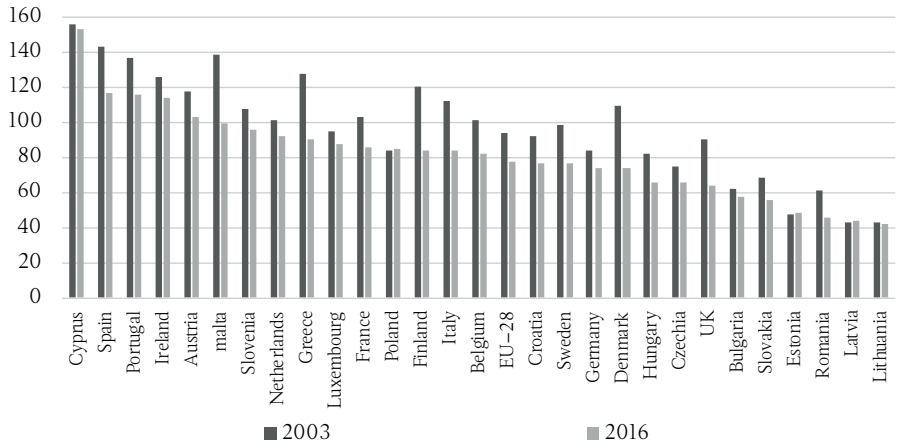
Source: Own preparation based on Eurostat (2018).

Chart 15.
Share of RES in the gross final energy consumption by sector in selected EU countries (in %)



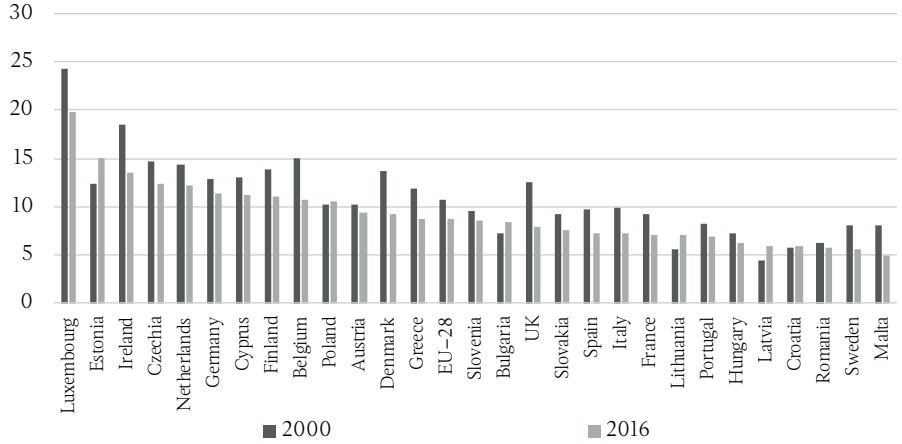
Source: Own preparation based on Eurostat (2018).

Chart 16.
Greenhouse gas emission in the EU countries (reference year 1990=100)



Source: Own preparation based on Eurostat (2018).

Chart 17.
Greenhouse gas emission in the EU countries (in tonnes per capita)



Source: Own preparation based on Eurostat (2018).