

## ORIGINAL ARTICLE


**Citation:** Jonek-Kowalska, I. (2019). Transformation of energy balances with dominant coal consumption in European economies and Turkey in the years 1990–2017. *Oeconomia Copernicana*, 10(4), 627–647. doi: 10.24136/oc.2019.030

Contact: izabela.jonek-kowalska@polsl.pl; Silesian University of Technology, Faculty of Organization and Management, ul. Roosevelta 26, 41-800 Zabrze

Received: 3.03.2019; Revised: 4.09.2019; Accepted: 26.10.2019; Published online: 25.12.2019

**Izabela Jonek-Kowalska**

*Silesian University of Technology, Poland*

 [orcid.org/0000-0002-4006-4362](https://orcid.org/0000-0002-4006-4362)

## Transformation of energy balances with dominant coal consumption in European economies and Turkey in the years 1990–2017

**JEL Classification:** F62; F64; O13

**Keywords:** *energy balance; European economies; links between energy policy and economy*

### Abstract

**Research background:** Energy policy is closely linked to economic development. Therefore, its optimization is an important issue especially in the contemporary European environmental conditions. EU regulations enforce a reduction of carbon dioxide emissions and the abandonment of non-renewable energy resources. Instead, they promote renewable energy sources. In this way, new legal and environmental circumstances are becoming the main reason for the transformation of energy balances, which is a real economic and technological challenge. This transformation requires a strategic and effective approach, especially in those countries which until now have used mainly hard coal in the energy sector.

**Purpose of the article:** According to above justification, the main purpose of the article is to identify the strategies for the transformation of energy balances that were implemented in the years 1990–2017 by chosen European countries and Turkey.

**Methods:** The study period covers the years 1990–2017, and the subject of the research at first applies to all European countries, and then to 7 countries selected due to their high share of bituminous coal in energy balance in the first year of the analysis, treated as the initial point of transformation (1990). As a result of this selection, 6 EU members and Turkey with the largest share of coal in energy production in the year 1990 are examined. Particularly, an analysis of the trends in their energy balances in the years 1990–2017 is conducted. The research uses data on non-renewable energy consumption and renewable energy resources and the total energy consumption. The research methodology includes: analysis of the structure and dynamics, evaluation of trends and comparative analysis and presentation of development strategies. At the end of the

article, a comparative analysis is carried out, the economic consequences of identified changes are assessed, and recommendations are formulated aimed at optimizing the structure of the energy balance in the future.

**Findings & Value added:** Generally, there are four theoretical and empirical patterns of transformation strategies of energy balances with dominant coal consumption: 1) using other non-renewable energy resources; 2) replacing non-renewable energy resources with renewable ones; 3) using nuclear energy instead of coal; 4) increasing coal consumption as available and efficient energy resource. It was found that the examined countries implement mainly the strategy in which the decreasing share of coal is made up for by an increasing share of gas. Additionally, we can observe an increase in the share of nuclear energy in France, the Czech Republic and the United Kingdom. In Spain and Germany, despite the use of nuclear power plants for the production of energy, the share of nuclear energy in the energy balances has systematically decreased in time. In all analyzed countries, we can also observe an increasing share of renewable sources in energy balances, however, this growth is very slow.

## Introduction

Economic and civilizational development is strictly associated with the efficiency of obtaining electrical and heat energy, which constitutes the driving force of all branches of industry and that is decisive in terms of the quality of life of households. In the current European conditions, use of basic energy media depends not only on their availability, but also on environmental regulations applicable in the European Union. Those regulations assume a shift from non-renewable energy sources and complete liquidation of carbon dioxide emissions associated with their use until 2050. Such an ambitious environmental objective is a difficult challenge for contemporary economies and their energy security. It is especially complicated in the case of those countries which widely used and use bituminous coal and lignite for the purpose of generation of energy and heating, since their use is associated with the highest emission of carbon dioxide to the atmosphere. Poland is also among those countries, since coal has constituted the dominant source of electrical and heating energy in its energy balance for many years now.

The process of transforming the energy balances started in the last decade of 20<sup>th</sup> century and now we could observe its first results. They show how particular countries coped with the UE environmental requirements. The results may create the best practices or might be a warning for non-changing economies. They also contribute to creating energy policies for the future.

Having regard to the aforesaid circumstances, the main purpose of this article is to identify the strategies for the transformation of energy balances that were implemented in the years 1990–2017 by chosen European countries and Turkey. The aforementioned objective is implemented in a theo-

retical aspect through determination of all possible options of transformation and in the practical aspect by studying the transformation patterns applied in particular European countries and Turkey.

The study uses comparative analysis in relation to the possibility to shape the energy balance. Moreover, the research methodology includes structure and dynamic indicators, as well as trend analysis. The study period covers the years 1990–2017, and the subject of the research at first applies to all European countries, and then to 7 countries selected due to their high share of bituminous coal in energy balance in the first year of the analysis, treated as the initial point of transformation (1990).

The structure of the article was appropriately adapted to implement the research objective indicated above. Its first element are literature studies related to the conditions of the European energy industry and strategies of its development. Then, it presents the study methodology including detailed stages of the analysis. The further part covers theoretical and practical strategies of transformation of energy balances including specification of determinants and consequences of their implementation. The summary formulates recommendations for the expected changes in the energy balances of studied European countries.

## **Literature review**

Currently, the source literature most often discusses the issues associated with the development of energy balances in two contexts related to environmental aspects. The first one relates to the problem of reducing carbon dioxide emissions (Moutinho *et al.*, 2018, pp. 605–622; Shamsavari & Akbari, 2018, pp. 275–291), while the second one to the efficiency of use of renewable energy sources (Papież *et al.*, 2018, pp. 918–934; Schmidt & Sewerin, 2019; Sharvini *et al.*, 2018, pp. 257–266; Vehmas *et al.*, 2018).

In addition to the environmental issues, the literature also discusses problem associated with internal energy safety and the risk associated with changes in the energy policy (Lupton & Cullen, 2018, pp. 176–188; Matsumoto *et al.*, 2018, pp. 1737–1748). It must be emphasized that decisions regarding transformation of the existing energy supply structure have long-term consequences and require significant infrastructural changes that are associated with high investment expenditure. This strand includes publications related to individual national energy balances and methods of their development, which constitute peculiar case studies of particular energy policies (Chomakhidze *et al.*, 2018, pp. 581–587; Szymonik & Bielecki, 2013).

Moreover, there are many publications regarding the relations between economic development and energy policy (Bąk & Michalak, 2018, pp. 155–174; Chen *et al.*, 2018, pp. 94–105; Shahbaz *et al.*, 2018, pp. 282–301), including issues associated with functioning of organized energy markets (Lee *et al.*, 2018, pp. 218–232; Vriesb, 2019, pp. 264–276; Kowalska-Styczeń *et al.*, 2018, pp. 1–30; Stankiewicz-Mróz, 2015, pp. 793–798) and planning of national energy needs.

The Polish source literature focuses on issues related to use of coal as an energy source due to its long-term domination in the energy balance. In the past and currently, there were and are numerous publications regarding the strategies of development of the Polish energy industry (Kudełko *et al.*, 2008, pp. 5–16; Gawlik, 2013, pp. 71–72; Turek, 2008; Spałek, 2014; pp. 538–548). The majority of them treat coal as the leading energy source due to its availability, amount, and social and political support for coal mining (Turek *et al.*, 2015, pp. 155–170; Jonek-Kowalska, 2015; Dubiński & Turek, 2017, pp. 1–12). Currently, the government is also preparing a new energy policy (assumptions of the existing policy of the Polish energy industry until 2030 are largely obsolete) until 2050, which, however, does not assume a complete abandonment of coal, but merely a slow reduction of the share of this resource in the energy balance.

Meanwhile, the environmental policy of the European Union is explicit, and one of its key objectives is the elimination of coal from energy balances in the European Union and in the countries that aspire to enter the community. The de-carbonization in the European Union was started by the so-called Climate package of 2008, which assumes, for example, the following: (1) reduction of emission of greenhouse gases by 20%, (2) an increase of energy efficiency by 20%, (3) as well as achieving 20% of the share of energy generated using renewable energy sources. In 2014, the aforementioned limits were increased to: 40%, 27% and 27%, respectively, and 2030 was set as the deadline for their implementation. Until 2050, the European Union plans further, radical reduction of emission of greenhouse gases, ultimately by 80%. In all indicated assumptions, 1990 is the point of reference to the level of reduction (Elshurafa *et al.*, 2018, pp. 122–134; Hąbek & Wolniak, 2016, pp. 399–420; Kmiecik & Michna, 2018; pp. 559–572; Michalak & Dziugiewicz, 2018, pp. 237–240; Ryszko, 2016, pp. 1–20).

Maintaining the share of coal at the previous level or increasing its share in the energy balances constitutes a significant threat to implementation of the aforementioned objectives, therefore, this article analyzes theoretical and practical changes in energy balances of the countries that use and used bituminous coal as one of the key energy sources. No such analysis has been carried out so far, and its crucial advantage is location and assessment

of particular economies and their energy policies in the context of environmental requirements of the European Union.

### **Research methodology**

As mentioned before, the point of reference for changes in climatic packages is the year 1990, and this is the year that marks the beginning of the analyses conducted in this article. The studies were carried out in the following stages:

1. Analysis of consumption of coal for power supply objectives based on energy consumption in Europe (analysis of trends, indicators of dynamics).
2. Determination of the structure of countries of the highest coal consumption in relation to the total European coal consumption using indicators (structure indicators).
3. Presentation of the strategies used for transformation of energy balances of significant share of bituminous coal.
4. Determination of practical paths of transformation of energy balances in the studied countries of significant share of bituminous coal (comparative analysis in international aspect and in relation to identified theoretical possibilities).
5. Indication of economic consequences of selection of specific options of transformation of energy balances and recommendations aimed at their compliance with the current environmental conditions.

The aforementioned stages aim to implement the main objective, which is to identify the strategies for the transformation of energy balances that were implemented in the years 1990–2017 by selected European countries and Turkey. The research sample was selected by taking into account the largest share of coal consumption in 1990 in European countries which was directly covered by the UE environmental regulations. The author is trying to answer the following research questions:

1. How has coal consumption changed in Europe in the context of decarbonization?
2. Which countries used the most coal in the energy balance in 1990?
3. How have these countries managed to transform their energy balances and adapt them to EU requirements?
4. Will the examined economies meet the growing EU environmental requirements in the future?

## Results

### *Coal consumption in Europe in the context of energy needs*

The first stage compares consumption of energy and coal as an energy source in Europe in the years 1990–2017. Results including appropriate functions of the trend are presented in Figure 1.

According to the data, the energy consumption systematically increased until 2008. After the economic crisis, we can observe a reduction of energy consumption below 2,000 Mtoe in 2009; a clear upwards trend of this variable began only in 2014, which confirmed mutual connection of the prosperity cycle and energy policy. Irregularity of the observed changes of energy consumption in the analyzed period is also confirmed by weak matching of the linear upwards trend ( $R^2=0.3117$ ).

In turn, coal consumption in Europe in the entire analyzed period is reflected by a well-adjusted linear downwards trend ( $R^2=0.7797$ ), which shows efficiency of the anti-coal policy and gradual resignation from use of this raw material for power supply purposes. It is worth mentioning that energy consumption in Europe has increased by over 6% and coal consumption has decreased by nearly 40% within the studied period of 28 years.

### *Coal consumption in the European countries in 1990 and 2017 — selection of the sample for further studies*

The further studies focus on the countries that were characterized by the largest share in the total coal consumption in Europe in the first year of the analysis, which is also the point of reference in the climatic policy in the European Union (Table 1).

In accordance with data included in Table 1, bituminous coal was and is used in many economies of the European Union. Nevertheless, the share of the vast majority of them in the total coal consumption does not exceed 3%. In 1990, the following countries were among the states that consumed the largest amounts of this resource: Germany, Poland and United Kingdom; in 2017, Poland and Germany remained in the lead, and were joined by Turkey. The share of the United Kingdom in the total coal consumption in Europe decreased by over four times in the analyzed period. However, in order not to restrict further studies to only 3 countries, for the purpose of the planned analytical goals, the economies whose share in the total coal consumption in Europe in 1990 exceeded 3% were selected, and it was decided to treat this value as significant in relation to considerable dispersion of the share in the remaining countries. Therefore, the following coun-

tries were included in the research sample: the Czech Republic, France, Germany, Poland, Spain, Turkey and the United Kingdom. The amount of coal consumption in the mentioned countries in the years 1990–2017, including trends associated with them, is presented in Figure 2 and 3.

According to data presented in Figure 2 and 3, the bituminous coal consumption in six out of seven studied countries systematically decreased, which was reflected by mostly well-adapted linear trend functions. Coal consumption as an energy source increased in time only in Turkey, whereas the growth since 2010 has been quite intensive compared to the previous twenty years of the analysis.

The reduction of consumption of bituminous coal in the analyzed period was the highest in France and the United Kingdom. However, due to changeable energy policy and no final decision to give up coal in the UK, the coal consumption was varied in the analyzed period. Moreover, the consumption of this raw material was reduced by 40% in the Czech Republic and Germany. The lowest reduction was achieved in Poland and Spain. In turn, in Turkey — as mentioned before — the coal consumption has almost doubled. However, it should be noted that, despite significant limitation of use of coal, the share of studied countries in the European consumption of this resource still exceeds 3% (the largest reduction in this share was recorded in the United Kingdom). It is worth adding that the energy policy in Spain was very changeable in analyzed period, and as a result we can observe intense fluctuation in coal consumption. Until 2010 the coal mines had been closed, and coal was replaced by gas. However, in 2011, after the disaster in Fukushima, the prices of gas increased and Spain, for economic reasons, decided to resume coal mining.

#### *Identification of paths of transformation of energy balances with significant share of coal*

Countries which use coal for energy and heat generation purposes to a large extent can potentially choose three strategies of energy balance transformation:

- I. replacing coal with other non-renewable resources:
  - a) oil,
  - b) gas.
- II. replacing coal with nuclear energy,
- III. replacing coal with renewable resources:
  - a) water energy,
  - b) wind energy,
  - c) solar energy,

- d) geothermal energy,
- e) biomass and other.

The common feature of all mentioned strategies is the reduction of carbon dioxide emissions, as even in a situation when coal is substituted with another non-renewable energy source, the level of emission will still be lower. The first strategy is relatively the easiest one to implement due to the availability of remaining non-renewable resources (including both those possible to be extracted and purchased), commonness of their usage and the possibility to use existing power supply infrastructure and already developed technological solutions.

Replacing coal with nuclear energy is a significantly more complicated venture, due to two key factors. Construction of a nuclear plant is costly, time-consuming, and is not easily accepted socially and ecologically.

Undoubtedly, the best solution, from the point of view of the current European climatic conditions, is the third strategy, in which coal is substituted with renewable energy sources. Nevertheless, its implementation largely depends on the availability and sufficiency of those sources. That is due to the fact that the use of solar, water or geothermal energy is restricted in certain regions due to existing and fixed geographical conditions. The use of those sources also requires a creation of new power supply infrastructure, which in turn demands additional capital expenditure and causes social and ecological disputes (for example in case of construction of wind farms or water power plants).

Moreover, each of the aforementioned strategies must take into account the question of energy security, that is the possibility of becoming independent from supply of energy sources or energy from the outside to the maximum extent possible, which significantly complicates selection of a specific strategy of transformation of energy balance, since it constitutes an additional decision criterion. It should also be emphasized that, regardless of the selected strategy, significant changes in energy balance are highly time-consuming and require transformation of the entire energy and economic infrastructure, therefore, the effects of their use are visible only after several or several dozen years. Having regard to the above, the energy policy must be thoroughly thought over and planned, since its change and/or modification of the effects of its implementation will not be possible in a short term.



*Identification of actual strategies of transformation of energy balances with significant share of coal*

This subsection identifies the actual directions of transformation of energy balances of the analyzed countries. Tables 3–9 present the structure of their energy balances in five-year intervals in the period from 1990 until 2015, and additionally in 2017, as the last year of the analysis.

Therefore, in accordance with data included in Table 3, the share of coal in the energy balance of the Czech Republic was reduced in the analyzed period from 64.90% to 38.53%. This raw material was replaced with mainly substitute non-renewable sources in the form of gas and oil (the total increase of the share by 12.17%). The share of nuclear energy also increased by almost 10 percentage points. Renewable energy sources had the smallest share in the energy sources that replaced coal (the total increase of share by 4.67 percentage points). Whereby, geothermal and biomass energy are the most intensively used renewable energy sources. In view of the above, it can be stated that the Czech Republic implements mainly strategy I in version a and b, as well as strategy II, and supplements it with strategy III to a small extent. This is a mix in which increasing share of oil and gas in energy balance causes a reduction of energy independence, since the Czech Republic does not extract those non-renewable resources. Nevertheless, it should be emphasized that this is partly made up for by increasing the share of nuclear energy that has been generated in this country since 1985.

Coal was replaced by nuclear energy to an even greater extent in France, in which the share of coal in the energy balance in the analyzed period decreased from 8.61% to 3.81% (Table 4). At the same time, the share of oil became significantly smaller. Those changes were accompanied by an increase in the share of gas (by 4.71 percentage points), nuclear energy (5.67 percentage points), and renewable energy sources (by 2.90 percentage points). Water and wind energy are the most intensively used renewable energy sources. Due to the above, France mainly uses strategy II, thus also maximizing its energy security. It additionally uses strategy I in version b, despite the fact that it does not extract gas in its territory.

In 1990, coal and oil dominated in the German energy balance (Table 5). In 2017, the share of coal decreased to 21.27%, while the share of gas (by 7.79 percentage points) and renewable energy sources (by as much as 13.52 percentage points) increased. Wind farms became the most important renewable energy source. Nevertheless, Germany is currently using nearly all available renewable sources, the share of which has significantly increased compared to 1990. Reduction of the share of nuclear energy by

4.53 percentage points should also be noted. Therefore, it may be stated that Germany implements strategy III, mainly in variant b, based on wind energy. It is complemented by strategy I a, which assumes an increasing use of gas. In the case of the latter, it means a reduction of energy security, since Germany can on its own meet merely about 20% of its demand for this resource. The remaining part must be imported from Russia. Moreover, Germany does not extract oil or coal, which additionally makes it more dependent on external supplies.

In Poland, the starting share of coal was the highest among the analyzed countries. Until 2017, the share decreased from 75.40% to 47.93%, nevertheless, it remains the leading energy source. It was mainly complemented by oil and gas, the share of which in meeting the energy demand was systematically increasing in the analyzed period. Also, the share of renewable sources has been constantly increasing, which included mainly wind energy and energy generated from biomass, however, the increase was slow and allowed for achieving the total share of renewable sources in energy generation at the level of 4.70% in 2017. In view of the above, Poland implements strategy I in variants a and b. Whereby, due to the fact that it does not extract oil and is able to meet merely about 23-25% of its current demand for gas on its own, its energy security decreases.

In 1990, the Spanish energy balance was dominated by oil and coal, complemented by nuclear energy (Table 7). In 2017, its structure became more differentiated. Oil remained the leading resource, but the share of coal decreased from 21.42% to 9.69%, while we can observe the growth of the share of gas (by 14.28 percentage points) and renewable energy sources (by 7.80% percentage points), including mainly wind, water, and solar energy. Therefore, Spain implemented strategy I in variant b, at the same time maintaining dominating share of oil in the energy balance. It was complemented by strategy III of quite differentiated internal structure. Due to the lack of own gas and oil sources, the energy security of Spain was decreasing in the analyzed period.

In the initial period of the analysis, the Turkish energy balance (Table 8) was dominated by oil and coal, the share of which was systematically decreasing in time together with the increase of the share of gas (growth by 22.34 percentage points). Therefore, Turkey implemented strategy I in variant b. The share of renewable sources has not significantly changed since 1990 (growth by 1.58 percentage points), nevertheless, due to significant use of water energy, and later also wind energy, it was one of the highest increases among analyzed countries, despite the fact that Turkey is not a member of the European Union, so it is not directly obliged to apply its climatic restrictions. It should also be noted that due to increasing demand

for energy, despite decrease of the share of coal in energy balance, the total consumption of this resource significantly increased in Turkey, which was emphasized at the beginning of this article.

In 1990, the share of non-renewable resources in the energy balance of the United Kingdom constituted over 92% with the dominance of oil and coal (Table 9), whereby the share of the latter decreased in 2017 from 22.01% to 4.70%. Decreased use of coal was replaced with higher share of gas (increase by 13.39%) and renewable energy sources (increase by 11.09%), including mainly wind and geothermal energy, as well as energy from biomass. Therefore, the United Kingdom implemented strategy I in variant b complemented by strategy III, whereby, due to the ability to cover approximately 50% of its demand for gas and oil on its own, it was not associated with radical reduction of energy security.

## **Discussion**

On the basis of the results of conducted studies, we can state that the use of coal as an energy source systematically decreases in Europe due to anti-coal policy of the European Union. Nevertheless, the countries that consumed and consume the largest amounts of this resource include: the Czech Republic, Germany, France, Poland, Turkey, Spain, and the United Kingdom. The energy balances of those countries have been covered by a detailed analysis in order to identify strategies of their transformation. On the basis of this analysis, it was found that the share of coal in meeting energy demand is decreasing in all analyzed economies, while particular countries implement mainly strategy I b, in which the decreasing share of coal is made up for by an increasing share of gas. Also, we can observe increase of the share of nuclear energy in France, the Czech Republic and the United Kingdom. In Spain and Germany, despite the use of nuclear power plants for production of energy, the share of nuclear energy in the energy balances systematically decreased in time.

In all analyzed countries, we can also observe an increasing share of renewable sources in energy balances, however, this growth is very slow, and strategy III is most intensively implemented only in Germany, where it is treated equally to strategy I and II. In the remaining countries it merely constitutes an addition to non-renewable and/or nuclear energy sources. The summary of transformations of energy balances is included in Table 10, which shows that non-renewable resources dominate the energy balances in all analyzed economies, however, their share decreases in time. Also, the share of renewable sources visibly increases compared to 1990. The

greatest progress in the use of ecological energy sources was recorded in Germany and the United Kingdom. Double digit share of those sources in energy balance can also be observed in Turkey and Spain.

In the case of Poland, the starting share of non-renewable sources was the highest, and its decrease was the lowest in the analyzed period. Also, the share of renewable energy sources is the lowest. This means that Poland is the least efficient in implementation of the climate objectives, despite the fact that the use of coal in the Polish economy systematically decreases. It should also be noted that the lack of oil deposits and limited possibilities in terms of obtaining gas reduce the Polish energy security.

Referring to the two required environmental paths of energy balance transformation described in the literature studies at the beginning of this article, it should be noted that all examined countries are trying to reduce the use of coal, and as a result reduce carbon dioxide emissions in the energy sector. Nevertheless, the share of non-renewable energy sources is growing very slowly and there is no majority or even significant replacement of non-renewable sources by renewable sources in any of the analyzed economies. This confirms the difficulties in using green energy sources described in the literature and observed in practice, which include: low sufficiency, cost-effectiveness and strong dependence on geographical and climatic conditions. Slow resignation from coal and low use of renewable sources is a serious threat to the implementation of EU environmental goals in examined countries, especially in Poland where the changes are the least radical and where in literature studies and practice the coal still remains the main energy source.

The identified trends and strategies also allow to state that the priority of energy security dominates in shaping energy balances. The examined economies are not giving up coal completely and are replacing it with in-house non-renewable and renewable sources. They continue to rely on their own energy supplies because they know and see the close interdependence of the energy balance and economic development exposed in the introduction.

## **Conclusions**

The presented study results relate mainly to changes in the structure of energy balance of particular economies and their consequences for the energy security and the natural environment. On the basis of the conducted analysis, we can clearly state that the share of coal as an energy resource used to meet demand for energy in current European conditions systematically decreases in the analyzed countries. Nevertheless, in none of the ana-

lyzed cases can we talk about an explicit pro-environmental direction of the changes, since coal is replaced by other non-renewable resources, mainly gas.

Those results confirm low sufficiency of non-renewable energy sources, and partially also their low efficiency, as well as the fact that the process of increasing their share in energy balances is time-consuming. Furthermore, the reduction of the share of coal — which constitutes own energy source — resulted in lower energy security in the majority of the analyzed countries, due to the fact that oil and/or gas that replaced it are imported. Therefore, it can be stated that the objectives of climate policy in the analyzed countries are not fully implemented, and the changes in energy balances take place at the expense of loss of energy independence.

The presented research refers only to aggregated statistical data. The author does not analyze the internal causes of changes and individual energy policies. The research also does not take into account the direct economic, environmental and social effects of using the identified strategies. The availability of renewable and non-renewable resources is also not assessed in detail. All the mentioned circumstances are the main research limitations.

Having regard to the above results and current environmental conditions, in the future we should focus on diversification of energy sources and on increasing the share of renewable sources in energy balances, and at the same time by optimizing energy security. Potential capabilities in this scope should be subject to further detailed studies and strategic considerations. Further research should also analyze the social, economic and environmental effects of using described strategies and strategies planned for the nearest future. In this context, one of the most important challenge is assessing and improving the availability and efficiency of renewable sources and their energy mix in energy balances. The challenge for theory and practice is also preparing legal regulations and financial support for implementing green energy sources in examined countries, especially in Poland.

## References

- Bąk, P., & Michalak, A. (2018). The problem of managers' remuneration in state-owned enterprises in the context of corporate governance. *Mineral Resources Management=Gospodarka Surowcami Mineralnymi*, 34(1).
- Chen, J., Zhou, Ch., Wang, S., & Li, S. (2018). Impacts of energy consumption structure, energy intensity, economic growth, urbanization on PM2.5 concentrations in countries globally. *Applied Energy*, 230. doi: 10.1016/j.apenergy.2018.08.089.

- Chomakhidze, D., Tskhakaia, K., Zivzivazde, L., Moseshvili, T., & Shamaevi, D. (2018). Electricity balance of Georgia: trends and prospects. *Energy Procedia*, 147. doi: 10.1016/j.egypro.2018.07.074.
- Dubiński, J., & Turek, M. (2017). Mining, mining ... and what's next? *Przegląd Górniczy*, 73(1).
- Elshurafa, A., M., Albardi, S. R., Bigerna, S., & Bollino, C. A. (2018). Estimating the learning curve of solar PV balance-of-system for over 20 countries: implications and policy recommendations. *Journal of Cleaner Production*, 196.
- Gawlik, L. (Ed.) (2013). *Coal for the Polish energy sector in the perspective of 2050 - scenario analyzes*. Katowice: Wydawnictwo Instytutu Gospodarki Surowcami Mineralnymi i Energią PAN.
- Hąbek, P., & Wolniak, R. (2016). Assessing the quality of corporate social responsibility reports: the case of reporting practices in selected European Union member states. *Quality & Quantity*, 50(1).
- Jonek-Kowalska, I. (Ed.) (2015). *Forecasting of import and export of hard coal in Poland in the aspect of national and international conditions*. Warszawa: Ce-DeWu.
- Kmieciak, R. & Michna, A. (2018). Knowledge management orientation, innovativeness, and competitive intensity: evidence from Polish SMEs. *Knowledge Management Research & Practice*, 16(4). doi: 10.1080/14778238.2018.1514997.
- Kowalska-Styczeń, A., Malarz, K., & Paradowski K. (2018). Model of knowledge transfer within an organization. *JASSS Journal of Artificial Societies and Social Simulation*, 21(2).
- Kudelko, M. (Ed.) (2008). *Scenarios for the development of the domestic hard coal sector until 2020 - technological foresight*. Kraków: Wydawnictwo IGSMiE PAN.
- Kudelko, M., Suwała, W., & Kamiński J. (2008). Variant forecasts of hard coal supplies for the country's economy by 2020. *Mineral Resources Management=Gospodarka Surowcami Mineralnymi*, 24(2/1).
- Lee, N. C., Leal, V. M. S., & Dias L. C. (2018). Identification of objectives for national energy planning in developing countries. *Energy Strategy Reviews*, 21. doi: 10.1016/j.esr.2018.05.004.
- Lupton, R. C., & Cullen, J. M. (2018). Useful energy balance for the UK: an uncertainty analysis. *Applied Energy*, 228. doi: 10.1016/j.apenergy.2018.06.063.
- Matsumoto, K., Doumpos, M., & Andriosopoulos, K. (2018). Historical energy security performance in EU countries. *Renewable and Sustainable Energy Reviews*, 82(2). doi: 10.1016/j.rser.2017.06.058.
- Michalak, A., & Dziugiewicz S. (2018). Development limitations and perspectives of renewable energy sources in Poland. *Management Systems in Production Engineering*, 26(4).
- Moutinho, V., Madaleno, M., Inglesi-Lotz, R., & Dogan, E. (2018). Factors affecting CO<sub>2</sub> emissions in top countries on renewable energies: a LMDI decomposition application. *Renewable and Sustainable Energy Reviews*, 90(C).

- Papież, M., Śmiech, S., & Frodyma, K. (2018). Determinants of renewable energy development in the EU countries. A 20-year perspective. *Renewable and Sustainable Energy Reviews*, 91. doi: 10.1016/j.rser.2018.04.075.
- Ryszko, A. (2016). Proactive environmental strategy, technological eco-innovation and firm performance - case of Poland. *Sustainability*, 8(2). doi: 10.3390/su8020156.
- Schmidt, T. S., & Sewerin, S. (2019). Measuring the temporal dynamics of policy mixes – an empirical analysis of renewable energy policy mixes' balance and design features in nine countries. *Research Policy*, 48(10). doi: 10.1016/j.respol.2018.03.012.
- Shahbaz, M., Zakaria, M., Shahzad, S. J. H., & Mahalik M. K., (2018). The energy consumption and economic growth nexus in top ten energy-consuming countries: fresh evidence from using the quantile-on-quantile approach. *Energy Economics*, 71. doi: 10.1016/j.eneco.2018.02.023.
- Shahsavari, A., & Akbari, M. (2018). Potential of solar energy in developing countries for reducing energy-related emissions. *Renewable and Sustainable Energy Reviews*, 90. doi: 10.1016/j.rser.2018.03.065.
- Sharvini, S., R., Noor, Z., Z., Chong, Ch., S., Stringer, L., C., & Yusuf, R. O. (2018). Energy consumption trends and their linkages with renewable energy policies in East and Southeast Asian countries: challenges and opportunities. *Sustainable Environment Research*, 28(6). doi: 10.1016/j.serj.2018.08.006.
- Spatek, S. (2014). Finding a new way to increase project management efficiency in terms of time reduction. *Engineering Economics*, 25(5). doi: 10.5755/j01.ee.25.5.8419.
- Stankiewicz-Mróż, A. (2015). Approach to the issues of leadership in the processes of companies' acquisitions. *Procedia Manufacturing*, 3. doi: 10.1016/j.promfg.2015.07.332.
- Szymonik, A., & Bielecki, M. (2013). Total logistic management – as condition of functioning of the logistically efficient company. In *Proceedings of Carpathian logistics congress 2013*. Retrieved from <http://blmm-conference.com/wp-content/uploads/BLIMM1707.pdf> 212-217.
- Turek, M. (Ed.) (2008). *Scenariusze technologiczne przemysłu wydobywczego węgla kamiennego*. Katowice: Główny Instytut Górnictwa.
- Turek, M., Jonek-Kowalska, I., & Hysa, B. (2015). Prognoza produkcji węgla kamiennego w perspektywie do 2030 roku - wyniki badań heurystycznych. In I. Jonek-Kowalska (Ed.). *Prognozowanie importu i eksportu węgla kamiennego w Polsce w aspekcie krajowych i międzynarodowych uwarunkowań*. Warszawa: CeDeWu.
- Vehmas, J., Kaivo-oja, J., & Luukkanen, J. (2018). Energy efficiency as a driver of total primary energy supply in the EU-28 countries – incremental decomposition analysis. *Heliyon*, 4(10). doi: 10.1016/j.heliyon.2018.e00878.
- Vriesb, L. (2019). Distributed energy resources and the organized balancing market: A symbiosis yet? Case of three European balancing markets. *Energy Policy*, 126. doi: 10.1016/j.enpol.2018.11.009.

### **Acknowledgements**

The paper was financed from statutory studies of the Institute of Economy and Information Technology no. BK 231/ROZ1/2018 (13/010/BK\_18/0029).



## Annex

**Table 1.** Share of particular countries in the total coal consumption in Europe in 1990 and 2017 [in %]

Country	Share in 1990	Share in 2017
Austria	0.83	1.06
Belgium	2.16	0.98
Bulgaria	1.77	2.12
Croatia	0.17	0.14
Cyprus	0.01	0.00
Czech Republic	6.40	5.41
Denmark	1.24	0.53
Estonia	1.20	1.52
Finland	1.07	1.39
France	3.86	3.06
Germany	26.75	24.04
Greece	1.64	1.64
Hungary	1.27	0.77
Iceland	0.01	0.04
Ireland	0.70	0.64
Italy	2.86	3.31
Latvia	0.14	0.01
Lithuania	0.16	0.07
Luxembourg	0.22	0.01
Macedonia	0.27	0.29
Netherlands	1.78	3.08
Norway	0.17	0.26
Poland	15.96	16.42
Portugal	0.58	1.18
Romania	2.59	1.92
Slovakia	1.59	1.12
Slovenia	0.32	0.40
Spain	3.91	4.54
Sweden	0.60	0.65
Switzerland	0.07	0.04
Turkey	3.26	15.04
United Kingdom	13.21	3.03
Other European regions	3.21	5.28
<b>Total Europe</b>	<b>100.00</b>	<b>100.00</b>

□ – countries of the largest share in the coal consumption in Europe.

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 2.** Change in coal consumption in 2017 compared to 1990 [in %]

Change	Country						
	Czech Republic	France	Germany	Poland	Spain	Turkey	United Kingdom
	-49.01	-52.27	-45.81	-37.96	-30.00	178.04	86.16

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 3.** Share of particular energy sources in the balance of Czech Republic in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	17.85	20.14	20.01	23.04	21.58	22.72	23.55
Gas	10.83	16.09	18.33	17.32	18.34	16.00	17.30
Coal	64.90	55.64	52.89	45.52	42.66	41.02	38.53
Nuclear energy	5.88	6.80	7.52	12.58	14.40	14.99	15.40
Hydroelectricity	0.54	1.11	0.97	1.21	1.43	1.00	1.02
Solar energy	0.00	0.00	0.00	0.00	0.32	1.26	1.19
Wind energy	0.00	0.00	0.00	0.01	0.17	0.32	0.32
Geothermal, biomass and other	0.00	0.23	0.29	0.33	1.10	2.68	2.69
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 4.** Share of particular energy sources in the balance of France in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	42.00	38.60	38.13	36.19	34.08	32.88	33.51
Gas	11.46	12.41	13.87	15.47	16.64	14.47	16.17
Coal	8.61	6.13	5.49	5.06	4.50	3.46	3.81
Nuclear energy	32.21	35.71	36.42	38.48	37.87	40.85	37.88
Hydroelectricity	5.52	6.92	5.82	4.39	5.54	5.08	4.68
Solar energy	0.00	0.00	0.00	0.00	0.05	0.68	0.87
Wind energy	0.00	0.00	0.00	0.08	0.88	1.98	2.31
Geothermal, biomass and other	0.20	0.22	0.26	0.33	0.43	0.60	0.76
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 5.** Share of particular energy sources in the balance of Germany in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	36.99	41.47	39.89	37.81	36.60	35.56	35.77
Gas	15.34	19.76	21.02	23.00	23.04	20.47	23.13
Coal	36.81	26.79	25.15	24.08	23.44	24.34	21.27
Nuclear energy	9.66	10.31	11.32	10.93	9.68	6.42	5.13
Hydroelectricity	1.10	1.44	1.66	1.32	1.44	1.33	1.33
Solar energy	0.00	0.00	0.00	0.09	0.81	2.71	2.69
Wind energy	0.00	0.10	0.63	1.83	2.65	5.64	7.20
Geothermal, biomass and other	0.09	0.13	0.32	0.96	2.34	3.53	3.48
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 6.** Share of particular energy sources in the balance of Poland in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	15.68	16.28	23.66	25.27	28.10	28.09	31.15
Gas	8.59	9.44	11.39	13.33	13.71	15.39	16.21
Coal	75.40	73.81	64.31	60.05	54.10	50.96	47.93
Nuclear energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroelectricity	0.31	0.45	0.54	0.54	0.65	0.43	0.57
Solar energy	0.00	0.00	0.00	0.00	0.00	0.01	0.04
Wind energy	0.00	0.00	0.04	0.44	2.04	2.75	2.73
Geothermal, biomass and other	0.01	0.02	0.06	0.37	1.40	2.35	1.36
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 7.** Share of particular energy sources in the balance of Spain in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	52.80	56.55	54.85	52.37	49.64	45.93	46.67
Gas	5.54	7.49	11.78	19.52	21.23	18.13	19.82
Coal	21.42	18.41	16.21	13.42	4.71	10.12	9.69
Nuclear energy	13.69	12.18	10.90	8.52	9.51	9.58	9.47
Hydroelectricity	6.41	5.08	5.18	2.65	6.49	4.71	3.01
Solar energy	0.00	0.00	0.00	0.01	1.09	2.32	2.34
Wind energy	0.00	0.06	0.83	3.13	6.74	8.25	8.01
Geothermal, biomass and other	0.14	0.22	0.26	0.39	0.59	0.96	0.99
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 8.** Share of particular energy sources in the balance of Turkey in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	49.51	39.10	43.51	37.26	30.45	32.15	30.95
Gas	5.82	29.15	16.32	26.04	28.61	28.74	28.17
Coal	33.64	21.80	30.56	26.09	29.20	25.26	28.28
Nuclear energy	0.00	9.25	0.00	0.00	0.00	0.00	0.00
Hydroelectricity	10.99	0.48	9.51	10.54	10.89	11.05	8.39
Solar energy	0.00	0.00	0.00	0.00	0.00	0.03	0.39
Wind energy	0.00	0.04	0.01	0.02	0.61	1.92	2.56
Geothermal, biomass and other	0.04	0.17	0.09	0.06	0.24	0.85	1.26
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: own study based on BP Statistical Review of World Energy (2017).

**Table 9.** Share of particular energy sources in the balance of the United Kingdom in the years 1990–2017 [in %]

Energy source	1990	1995	2000	2005	2010	2015	2017
Oil	40.14	39.10	36.09	37.48	36.48	38.44	39.89
Gas	22.01	29.15	38.31	36.80	39.68	31.74	35.40
Coal	30.30	21.80	16.15	16.12	14.49	11.92	4.70
Nuclear energy	6.94	9.25	8.46	7.95	6.59	8.19	8.32
Hydroelectricity	0.54	0.48	0.51	0.48	0.38	0.73	0.70
Solar energy	0.00	0.00	0.00	0.00	0.00	0.88	1.36
Wind energy	0.00	0.04	0.09	0.28	1.09	4.69	5.87
Geothermal, biomass and other	0.06	0.17	0.39	0.89	1.30	3.40	3.76
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

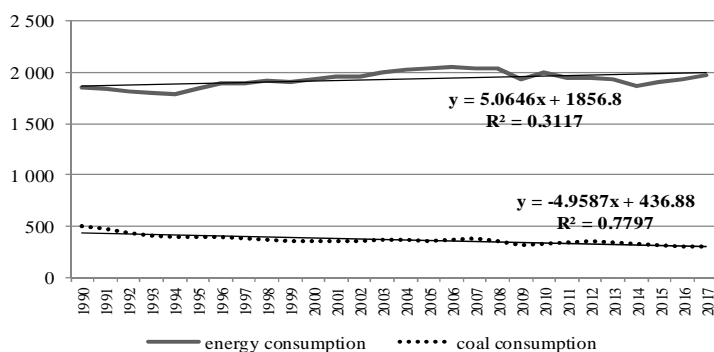
Source: own study based on BP Statistical Review of World Energy (2017).

**Table 10.** Share of non-renewable, renewable, and nuclear energy sources in balances of analyzed countries in 1990 and 2017 [in %]

Energy sources		Country						United Kingdom
		Czech Republic	France	Germany	Poland	Spain	Turkey	
Non-renewable	1990	93.58	62.07	89.15	99.68	79.76	88.98	92.45
	2017	79.38	53.49	80.17	95.30	76.18	87.40	79.99
Nuclear	1990	5.88	32.21	9.66	0.00	13.69	0.00	6.49
	2017	15.40	37.88	5.13	0.00	9.47	0.00	8.32
Renewable	1990	0.54	5.72	1.19	0.32	6.55	11.02	0.60
	2017	5.22	8.63	13.52	4.70	14.35	12.60	11.69

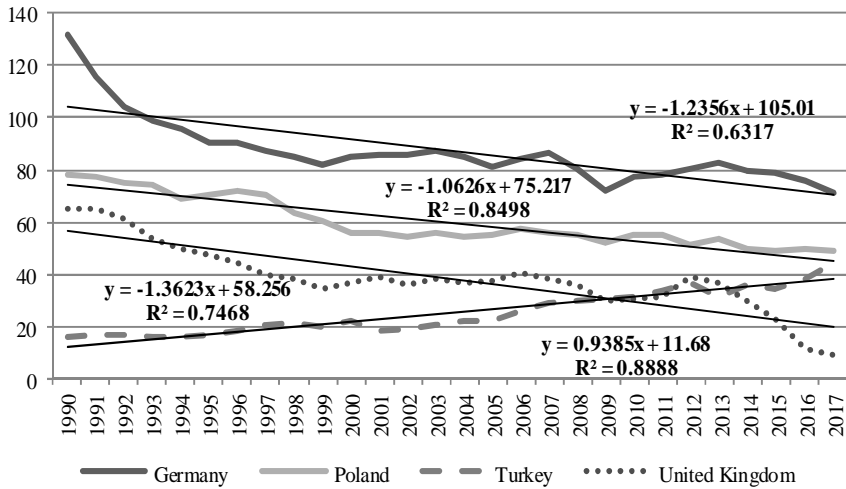
Source: own study based on BP Statistical Review of World Energy (2017).

**Figure 1.** Consumption of energy and coal as an energy source in Europe in 1990–2017 (in Mtoe)



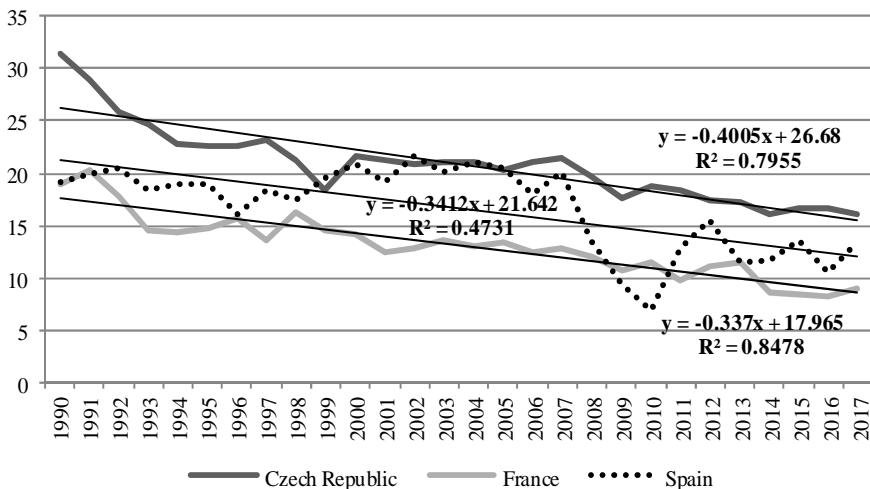
Source: own calculations based on BP Statistical Review of World Energy (2017).

**Figure 2.** Coal consumption in Germany, Poland, Turkey and the United Kingdom in the years 1990–2017 (in Mtoe)



Source: own study based on BP Statistical Review of World Energy (2017).

**Figure 3.** Coal consumption in Czech Republic, France and Spain in the years 1990–2017 (in Mtoe)



Source: own study based on BP Statistical Review of World Energy (2017).