Review Article

Tadeusz Olkuski*, Wojciech Suwała, Artur Wyrwa, Janusz Zyśk, Barbara Tora

Primary energy consumption in selected EU Countries compared to global trends

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Abstract: The article shows the consumption of primary energy carriers in selected European Union (EU) countries, including Poland. The trend of consumption of primary energy carriers was compared with the global trend, which is different from that observed in the EU. The consumption of primary energy sources has been increasing steadily for many decades, due to the growth of the world population and the aspirations of developing countries to raise the standard of living of their citizens. In the EU, the opposite trend, i.e., a decrease in primary energy consumption, has been observed since 2007. This article presents tables and graphs showing these phenomena. The authors tried to answer the following questions: (a) What influences the decrease in demand for primary energy in highly developed countries? (b) Why the demand in less-developed countries is constantly growing? The trends in countries, such as Germany, France, the United Kingdom, Italy, and Poland, i.e., countries with the most developed economies in the EU and the home country of the authors, were analyzed.

Keywords: primary energy, consumption, energy policy

*** Corresponding author: Tadeusz Olkuski,** Department of Sustainable Energy and Fuels, The Faculty of Energy and Fuels, AGH University of Science and Technology, Kraków, Poland, e-mail: olkuski@agh.edu.pl
Wojciech Suwała: Department of Sustainable Energy Development, The Faculty of Energy and Fuels, AGH University of Science and Technology, Kraków, Poland, e-mail: suwalaw@agh.edu.pl
Artur Wyrwa: Department of Sustainable Energy Development, The Faculty of Energy and Fuels, AGH University of Science and Technology, Kraków, Poland, e-mail: awyrwa@agh.edu.pl
Janusz Zyśk: Department of Sustainable Energy Development, The Faculty of Energy and Fuels, AGH University of Science and Technology, Kraków, Poland, e-mail: jazysk@agh.edu.pl
Barbara Tora: Department of Environmental Engineering, The Faculty of Mining and Geoengineering, AGH University of Science and Technology, Kraków, Poland, e-mail: tora@agh.edu.pl

1 Introduction

Primary energy consumption was once perceived as an indicator of the civilization development. The economic progress of individual countries was measured by the consumption of both primary and secondary energy, the use of coal and steel, and electricity. In later years, it was realized that such a constant drive for development through the unlimited increase in the use of natural resources is ineffective and harmful to the natural environment. Therefore, measures are taken to protect the natural resources by making efficient use of them. The consumption of primary energy carriers in selected European Union (EU) countries, including Poland, is discussed further in this article.

What do we mean by primary energy? Primary energy carriers are directly derived from a natural source. According to Statistics Poland [1], this group includes the following:

- bituminous coal for electricity production (including coal recovered from spoil tips),
- bituminous coking coal,
- lignite,
- crude oil (including gasoline),
- high-methane natural gas (including gas from demethanation of bituminous coal mines),
- nitrogen-rich natural gas,
- peat for heating,
- firewood,
- solid fuels from plant and animal waste,
- solid and liquid industrial wastes (excluding petroleum products recovered for reprocessing),
- municipal waste,
- biogas obtained from landfills and sewage treatment plants,
- other raw materials used for energy purposes (methanol, ethanol, and additives),
- water power for electricity generation,
- wind power for electricity generation,
- solar energy for heat and power generation,
- geothermal energy for heat and power generation.

2 Global primary energy consumption

The world's developing economies need more and more energy. Energy needs started to increase especially since the industrial revolution, that is, from the second half of the eighteenth century. The use of energy resources allowed for the unprecedented development of civilization and improvement of living conditions. The work has become easier, and it does not require as many people and as much time to get it done. Figure 1 shows primary energy consumption between 1965 and 2019, which allows us to take a closer look at the world's primary energy consumption. As can be seen, the consumption is systematically increasing. This is due to several factors including but not limited to the population growth, which causes greater energy needs of developing societies, and the aspiration of citizens of developing countries to raise their standard of living. The upward trend continues despite the concerns expressed by various environments, mainly ecological ones, warning against excessive exploitation of energy resources that will eventually be depleted.

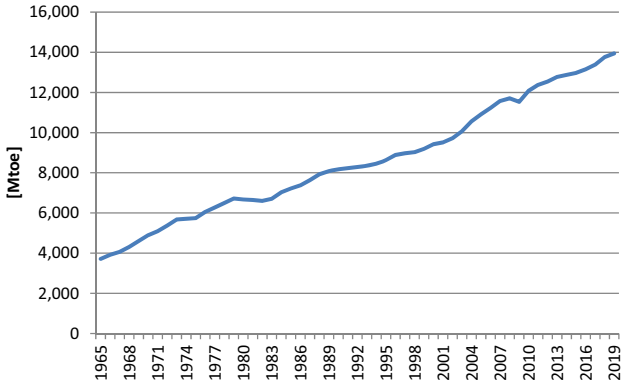

Figure 1: Global primary energy consumption in the years 1965–2019. Source: own work based on ref. [2].

Naturally, fossil fuel resources are sufficient to meet our current level of demands and even the needs of future generations, but nevertheless they are limited and should be cared for and used only to the extent that is necessary to maintain the current level of public welfare. Crude oil resources amount to 244.6 billion tons, which at the current level of production should last for about 50 years. Natural gas resources amount to 198.8 bcm, which, taking into account the current production levels, should also last for about 50 years. In the case of bituminous coal, the situation is even better, as its reserves amount to 1069.64 billion tons, which, at the current level of production, should last for 132 years [2].

As mentioned above, one of the factors affecting the continuous increase in demand, and thus also the global primary energy consumption, is the demographic factor. Figure 2 presents, based on data of the United Nations, Department of Economic and Social Affairs from 2019 [3], world population changes from 1950 to 1 July 2020. It is clearly visible that the global population is constantly growing, and there is no indication that this trend will stop. Currently, the most populous country in the world is China with almost 1.4 billion people, followed by India – about 1.3 billion people. According to the UN, India will soon become the most populous country in the world. The population of Africa is also growing. Africa's population is projected to double by 2050. The greatest increase is expected to occur in the most populous country of this continent – Nigeria. In general, according to UN forecasts, the world's population will rise to 8548.5 million in 2030 and 9,735 million in 2050. The demographic increase in Europe will be different. Currently, the population of

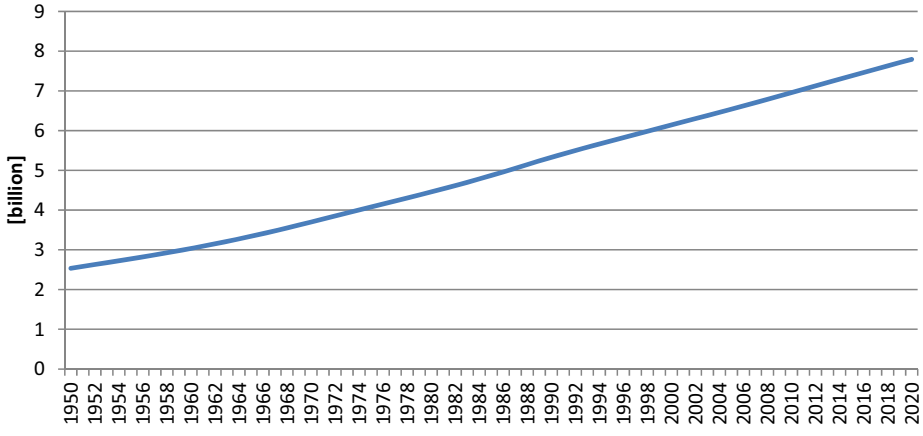

Figure 2: World population between 1950 and 2020. Source: own work based on ref. [4]. Note: as of 1 July 2020.

Europe is 747.2 million people, and it is to decrease to 741.3 million people in 2030 and to 710.5 million people in 2050 [3]. However, it should be emphasized that the population of Europe is only 9.5% of the world population, so demographic trends in Europe have little effect on the world population.

3 Primary energy consumption in the EU

The eighteenth century was a time of an unprecedented change in the economy, when the implementation of new technologies, the departure from agriculture and manufacturing, and the transition to large-scale production in modern, for the time, factories using new machines and devices took place. It was associated with an increase in energy demand, and the main source of energy was coal. The United Kingdom, until the end of the 1980s, was one of the major producers and users of bituminous coal in the world. However, the reforms introduced by Prime Minister Margaret Thatcher led to the decline of coal mining in the United Kingdom. Coal began to be replaced with cleaner fuels, such as oil and natural gas, discovered at that time in the North Sea. The development of the industry took place in other European countries as well. The heavy industry was mainly developed within the framework of the European Coal and Steel Community established in 1952. The establishment of this international organization is considered the beginning of European integration, the result of which is the present EU. Figure 3 shows the development of primary energy consumption in the countries currently belonging to the EU in the years 1965–2019.

Until 2007, primary energy consumption was increasing, initially quickly, then at a slower pace. Several periods of consumption decrease are clearly visible. The first significant decrease was observed in the mid-1970s and coincided with the first oil crisis. The second decrease occurred in the late 1970s with the second oil crisis and lasted until 1983. The third decrease was observed at the turn of the 1980s and 1990s and coincided with the period of political and economic transformations in the former Eastern Bloc countries now belonging to the EU. The crisis in 2007 resulted in a further reduction in energy consumption, which peaked in 2009. After a brief increase in 2010, consumption started to decrease again. The current downward trend can be explained by the relocation of heavy industry outside Europe and the introduction of policies aimed at

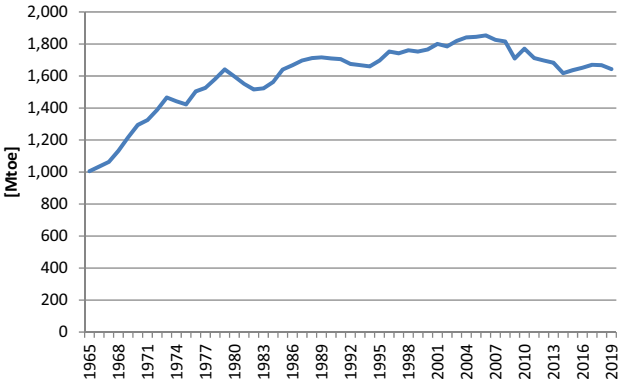

Figure 3: Primary energy consumption in the countries belonging to the European Union in the years 1965–2019. Source: own work based on ref. [2]. Note: excludes Estonia, Latvia, and Lithuania prior to 1985 and Slovenia prior to 1990.

efficient energy management and savings. Environmental organizations established in various countries, especially in Germany, have a huge impact on this process.

Table 1 shows the consumption of primary energy in the most economically developed countries of the EU and in Poland. The table shows data from 2000 at 5-year intervals and the latest data published by Eurostat for 2018.

The changes taking place over the last two decades in the countries of the EU mentioned in Table 1 are presented in Figures 4–7, which contain graphs of primary energy consumption in these countries in the years 1999–2018.

Primary energy consumption in Germany changed in the analyzed period from 315.57 Mtoe in 1999 to 291.75 Mtoe in 2018. The analyzed period can be divided into two intervals that clearly differ in the amount of energy consumption. The first covers the years 1999–2006, when the primary energy consumption remained relatively stable or even increased significantly, as was the case in 2001 and 2006. The last year was characterized by the highest primary energy consumption in Germany in the entire last two decades. Later on, the consumption followed a

Table 1: Primary energy consumption in selected EU countries, Mtoe

	2000	2005	2010	2015	2018
Germany	317.13	321.62	315.15	295.93	291.75
France	239.78	260.92	254.45	244.40	238.91
United Kingdom	221.96	223.48	205.09	183.11	176.27
Italy	166.11	180.83	167.28	149.12	147.24
Poland	84.85	87.96	96.56	90.06	101.06
EU-28	1619.41	1721.40	1663.86	1537.61	1551.92

Source: own work based on ref. [5].

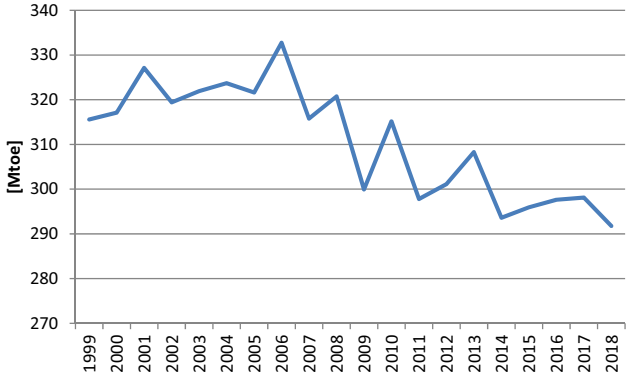

Figure 4: Primary energy consumption in Germany in the years 1999–2018. Source: own work based on ref. [5].

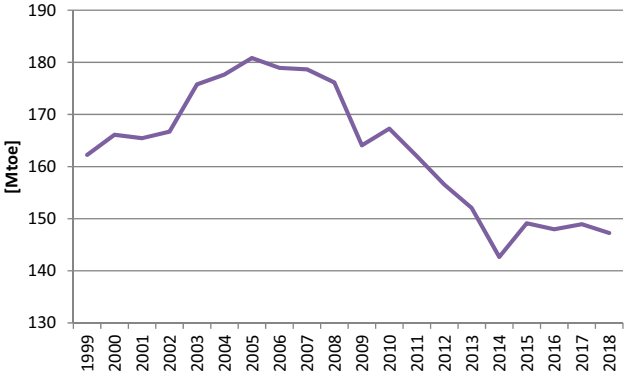

Figure 7: Primary energy consumption in Italy in the years 1999–2018. Source: own work based on ref. [5].

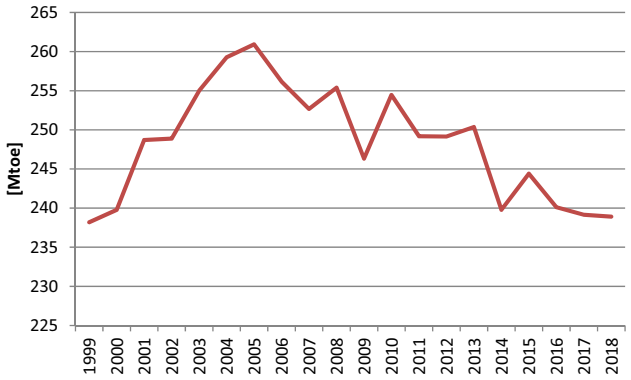

Figure 5: Primary energy consumption in France in the years 1999–2018. Source: own work based on ref. [5].

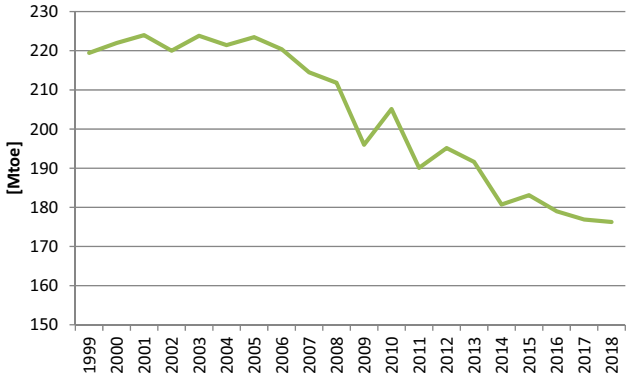

Figure 6: Primary energy consumption in the United Kingdom between 1999 and 2018. Source: own work based on ref. [5].

downward trend, with the decreases occurring abruptly. After a significant decrease in 1 year, there was an increase in the next one; however, the increase was much smaller than the decrease in the previous year. The difference in consumption between the beginning and the end of the analyzed period is 23.82 Mtoe, and the difference between the highest and lowest consumption is 41.0 Mtoe. A further reduction in consumption is expected in the coming years. Already in 2010, the German government planned to reduce primary energy consumption by 20% by 2020 and by 50% by 2050 [6]. According to the latest statements of German government officials, Germany will strive to reduce energy consumption by 30% by 2030 compared to 2008.

France is the second largest economy in the EU and so it is natural that it consumes a lot of energy. Unlike Germany, France consumed almost the same amount of primary energy both in 2018 and 1999 (20 years earlier). In 2018 it was 238.91 Mtoe, while in 1999 it was 238.19 Mtoe. A careful comparison of these figures shows that the consumption in the analyzed period increased by 0.72 Mtoe. However, it is worth looking closely at the chart. In the years 1999–2005 the consumption grew continuously, reaching 260.92 Mtoe in 2005. Since 2005, consumption, similar to Germany, has been systematically reduced, increasing several times, as it was in 2008, 2010, 2013, and 2015. In 2018, the most consumed primary energy source in France was, as in previous years, nuclear energy (93.5 Mtoe), followed by crude oil (78.9 Mtoe), natural gas (36.7 Mtoe), hydropower (14.5 Mtoe), renewable energy (10.6 Mtoe), and coal (8.4 Mtoe) [7].

The United Kingdom kept its primary energy consumption more or less constant between 1999 and 2005 at around 220 Mtoe. The consumption peaked in 2001 at 223.98 Mtoe. Since 2005, a steady decrease in consumption, from 223.48 Mtoe in 2005 to 176.27 Mtoe in 2018, has been observed. Thus, it can be seen that in the analyzed 20 years, the primary energy consumption decreased by approximately 20%. The reduction in energy consumption is explained by the transformation of the UK's energy system aimed at the promotion of energy efficiency, the thermal modernization of buildings, and the widespread

introduction of LED lighting. This is, of course, the right course of action that should be followed. It should be remembered, however, that the United Kingdom has swung significantly toward isolationism in recent years and its efforts to leave the EU (successfully completed) had a negative impact on the economy, slowing its development. According to Bloomberg Economics [8], Brexit has already cost the UK £130 billion ($170 bn), and by the end of 2020 the cost will increase by another £70 billion.

Italy is one of the seven most industrialized countries in the world and the third largest economy in the EU. The primary energy consumption in the years 1999–2018 was variable. From 1999 to 2005, the consumption continued to increase from 162.25 to 180.83 Mtoe, which was the highest value in the analyzed period. In the following years, the consumption decreased to reach the lowest value of 142.66 Mtoe in 2014. At that time, only the year 2010 was characterized by a slight increase in consumption by 3.2 Mtoe compared to the previous year. A more significant increase was recorded in 2015, when it amounted to 149.12 Mtoe, i.e., it increased compared to 2014 by 6.46 Mtoe. In the following years, the consumption remained stable and in 2018 it amounted to 147.24 Mtoe. Italy's per capita energy consumption is 19% lower than the EU average [9]. Natural gas, followed by crude oil, is the most important energy source in Italy. This is set to change in the near future. According to the Italian National Energy Strategy [10], the country is to achieve a 28% share of renewable energy sources (RES) in total energy consumption by 2030.

4 Primary energy consumption in Poland

Poland is the only one of the five analyzed countries where energy consumption is increasing. This is due to various factors, both positive and negative. The positive factors include the economic development of the country, the creation of new companies, or the GDP growth. For example, in 2017, the GDP growth rate in Poland was 4.6% (vs the EU average of 2.5%). The increase in the consumption of energy carriers can be seen as a continuation of the negative trend of low energy management efficiency in Poland. Figure 8 shows the primary energy consumption in Poland in the years 1999–2018.

In 1999, the consumption of primary energy in Poland amounted to 89.47 Mtoe, but in the following year it

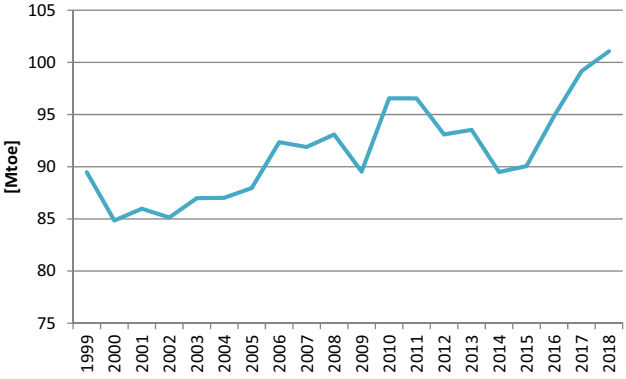

Figure 8: Primary energy consumption in Poland in the years 1999–2018. Source: own work based on ref. [5].

decreased significantly. Until 2010–2011, energy consumption increased with the exception of 2009, when there was a decrease from 93.09 Mtoe in the previous year to 89.53 Mtoe. The following 3 years were characterized by a decrease in energy consumption to the level of 89.49 Mtoe. Since then, the consumption of primary energy in Poland has been growing steadily. In 2018, for the first time in the present century, it exceeded 100 Mtoe, or, more precisely, 101.06 Mtoe.

Figure 9 shows the structure of primary energy consumption in Poland in 2018.

As in the entire post-war period, coal accounted for the largest share in primary energy mix in Poland in 2018. At that time, 50.5 Mtoe of this raw material was used. The second most consumed primary energy source was crude oil – 32.8 Mtoe, and the third was natural gas – 17.0 Mtoe. The share of RES and water energy in primary energy consumption was low. After calculating the percentage shares of individual energy sources in the consumption of primary energy in Poland, it is clear that most of the primary energy consumed came from coal, in this case both bituminous coal and lignite. The share of coal in primary energy consumption in Poland in 2018 was 48.0%, which means that almost half of the energy was produced from this raw material. The second most consumed primary energy source was crude oil, used mainly in transport, with a share of 31.2%, followed by natural gas with a share of 16.1%. RES and hydropower accounted for 4.2 and 0.4%, respectively. The energy consumption in households (excluding motor fuels) accounted for 18.2% [11]. In the years 2002–2018, the share of space heating consumption in total energy consumption decreased, which was related to the implementation of thermal efficiency improvement of buildings, while the share of energy consumption for heating water, cooking meals, and lighting with electrical devices increased.

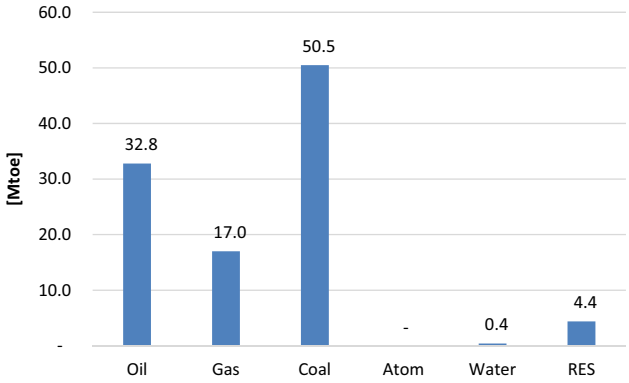

Figure 9: Primary energy consumption in Poland in 2018. Source: own work based on ref. [2].

As for the prospects of primary energy consumption in Poland, the draft of the Energy Policy of Poland until 2040 [12], a government document proposed but not yet approved by parliament, covering the demand for primary energy is one of the main principles of the state's energy security. The primary raw material for the production of electricity is bituminous coal, followed by crude oil, natural gas, lignite, and renewable sources. The document states that Poland has resources of all the above-mentioned raw materials; however, there are not enough resources to achieve a complete energy independence of the country. Therefore, although the coal should be obtained from domestic mines, it can be imported, if justified. Bituminous coal is the basis of the national energy balance, and its consumption is about 74 million tonnes, so it is the most important energy resource in our country. The crude oil consumption is around 26 million tons, and domestic production only covers 4–5% of the needs, which makes it necessary to rely on imports. Natural gas consumption amounts to 17 billion m^3, of which domestic production meets only a quarter of the needs.

5 Environmental protection

In recent years, great emphasis has been placed on the protection of the natural environment. Therefore, efforts are made to reduce emissions of sulfur dioxide, nitrogen oxides, carbon dioxide, and dust. To achieve this, a decarbonization process is being introduced in Poland, which, in the long term, will improve the air quality and extend the life of citizens. However, these are time-consuming activities, but the results of calculations by experts from the University of Science and Technology, Faculty of Fuels and Energy showed that the decrease in PM2.5 emissions envisaged in the analyzed scenarios in 2050 will lead to a reduction in the number of lost years of life by about 35,000 and an avoidance of external costs by EUR 2.4 billion [13].

So it is worth making such efforts. Regulations on emission standards for various types of installations [14] and quality certificates [15] are also introduced in Poland, which prohibit the use of low-quality fuels. Growing environmental awareness of the society and rising emission allowance prices exceeding EUR 40/t [16] result in a decline in the share of electricity from fossil sources. The reduced share of fossil resources, especially coal, in the energy mix reduces CO_2 emissions. In 2018, the professional energy sector in Poland emitted 140.0 million tonnes of CO_2, and in 2019 only 127.3 million tonnes were emitted [17]. Therefore, a decrease by 12.7 million tonnes was recorded and this trend will continue in the coming years.

Poland's energy policy until 2040 assumes a reduction in the share of coal in electricity production from approximately 70% now to 56% in 2030, while the share of RES in gross final energy consumption will increase to 23% [18]. This is not much compared to the rest of the EU, but the trend is similar. Ember and Agora Energiewende's fifth annual report tracking Europe's electricity transition was published on 25 January 2021; it revealed that renewables overtook fossil fuels to become the EU's main source of electricity for the first time in 2020 [19]. However, actions aimed at climate protection are taken in Poland, for example, the National Plan for Energy and Climate for 2021–2030 [20].

From 31 March 2021, applications may be submitted to support projects/investments involved in the construction of new or reconstruction of old electricity generation units using solar radiation energy (above 2 MWe). PLN 80 million has been allocated to co-finance the projects [21]. Work is also underway on the production and use of hydrogen. Jastrzębska Spółka Węglowa SA (JSW SA) is one of the leading companies conducting research on obtaining hydrogen from coke oven gas, i.e., using the primary chemical energy contained in coal and replacing it with clean fuel, which is hydrogen. The coking plants belonging to the JSW Group have a production potential of 72,000 tonnes of hydrogen per year [22]. There are many possibilities for switching from conventional energy, i.e., the use of chemical energy contained in fuels, to renewable energy, but as research [23] shows, from the point of view of energy security, changes should be made slowly to ensure continuity of supplies of both fuels and energy.

6 Conclusion

Taking into account the events on world energy markets, it is difficult to forecast the primary energy consumption in the future. On one hand, we are witnessing an increasing use of energy in developing countries, which is due to the growing population in these countries, as well as the efforts to raise the standard of living to the level found in developed countries. On the other hand, developed countries impose restrictions on themselves in the form of increasingly stringent environmental protection standards, reduce fuel and energy consumption, and take decisive measures to protect the climate and life on Earth. These measures are already bearing fruit in the form of decreasing fuel and energy consumption, and the forecasts predict even more restrictive measures. This applies especially to the economies of the European Community. Poland, as a member of the EU, is also obliged to implement energy transformation aimed at reducing the use of fossil fuels, especially steam coal, and the development of RES. In recent days, during negotiations between government representatives and trade unions representing the mining industry, it was agreed to phase out power coal mines by 2049. Until then, the exploitation of coal will be limited and unprofitable mines will be gradually closed.

The reduced primary energy demand in Germany, France, the United Kingdom, and Italy is due to industrial restructuring in these countries, as well as the so-called carbon leakage, i.e., the escape of energy-intensive industries outside the EU due to increasing fees for emission allowances, as well as the transfer of employees to the service sector. The main goal of the EU is the energy transformation consisting in moving away from fossil fuels and replacing them with RES. However, it should be remembered that these are unstable sources that cannot currently constitute the basis of the energy system. This is clearly illustrated by the example of Sweden, where the switch to green energy and the closure of the Ringhals nuclear reactor led to a shortage of electricity in February this year.

Currently, the biggest unknown factor is the economic impact of the COVID-19 pandemic. The lockdown, introduced in many countries, caused enormous economic losses, which will take many years to recover. In Poland, according to experts from Money.pl [24], the spring lockdown cost the economy over PLN 50 billion, and in the event of another lockdown, it would be up to PLN 150 billion. The state will not be able to borrow such money, and if it were to be printed, there would be serious economic problems. The adjusted budget deficit is expected to reach PLN 110 billion, as spending on anti-covid measures increased and production and sales fell. In addition, consumers reduce spending due to uncertainty about their future incomes. Fuel consumption is falling as a result of the reduced demand for travel due to health risks of COVID-19. The acute crisis in the tourism and transport industries is already being felt, and the situation may even worsen. Thus, at least until the end of the pandemic, primary energy consumption in most countries of the world will be much lower than in previous years.

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Ethical approval: The conducted research is not related to either human or animal use.

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