Renewable Energies as a Substitute for Fossil Fuel Resources in Poland

Aleksander Wasiuta (aleksander.wasiuta@up.poznan.pl)

Poznan University of Life Sciences, Faculty of Economics, Department of Economics

Original article

Keywords: renewable energy, transmission network, fossil fuel substitutes, transmission networks

Posted Date: April 5th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-247113/v1

Abstract

Background

The characteristic feature of modern energy sector in the EU is the development of environmentally friendly technologies based on renewable energy sources (RES). The use of alternative and RES contributes to resolving not only energy efficiency issues, but many of the environmental, economic and social problems. RES are also one of the priorities of the world's low carbon policy and reducing CO2 emissions into the atmosphere. Growing electrical energy consumption and increasing integration of RES in power systems have led to new challenges, thus it is required to investigate and properly analyze the impact of integrated RES on the power system as a substitute for fossil fuel resources.

Results

The aim of the article is to show the possibilities of developing RES in Poland in the context of environmental protection, energy self-sufficiency and international obligations. The depletion of primary energy sources and the increase in emissions of greenhouse gases to the atmosphere forces undertaking certain activities, aimed at seeking substitutes for fossil fuels. According to the author’s analysis, RES are the best and safest substitutes for traditional energy resources such as fossil fuel.

Conclusions

The author examines electricity production mix in EU counties and compares it to Polish energy sector. Taking into consideration the transmission network density in Poland, while energy sector changes its structure and expands, the mix of technologies deployed to produce electricity determines the associated burden on transmission networks. Polish energy sector development in the context of modernization of transmission grid provides an opportunity for investors to prepare the energy system for increasing the share of renewable energy sources. In the process of implementing the appropriate solution, the experiences of other countries that have significantly increased the share of renewable energy in the past could be used. This article presents the main areas of action that may facilitate the further integration of different energy sources in the specific context of Poland's changing energy system. Not all integration options will be important for Poland at the same time.

Introduction, Literature Review And Research Contribution

The paper is theoretical in nature and contains an analysis of experiences and models of renewable energy (RES) development in the European Union countries with the background of pro-ecological economic development, with particular emphasis on the possibility of using these experiences in Poland. The paper is also aimed at conducting research on the possibilities of developing RES, explaining the causes and nature of barriers that inhibit these processes, and emphasizing the benefits resulting from this for local governments as a result of the implementation of appropriate investments.

This paper uses scientific studies published mainly in Polish and English languages as well as statistic data from Ministry of Energy in Poland, Eurostat databases, polish statistics office, etc. The publications authored by Yankelovich D., Wojnowski J., Tomaszewski K., Nyman J., Maj R. are of the utmost importance for the scientific analysis of the development of Polish renewable energy sector, taking into account European conditions and experiences, directly and indirectly related to the development of energy sector.

In the last twenty years, the interest in environmental protection issues, including the development of renewable energy sources, has increased in scientific literature in Poland. This is so not only because of the obligations towards the signed EU strategies and constantly increasing demand for energy, but also because of the development of the awareness of the society and entrepreneurs who see future business potential in this field. Furthermore, it is worth highlighting that the problems of international energy security in the 21st century have been given important attention in different scientific papers.

Numerous articles and scientific publications reflect the problem of energy security, energy dependence of the EU and Poland on energy supplies from abroad, mostly from Russia. In Poland, issues related to energy security should be treated as an important element of national security. This topic is important and attractive in terms of research, therefore there are a large number of sources, which, however, are limited to a small number of monographs, and the dominant role is played by analyzes, articles and chapters in collective works devoted to issues in the field of security theory. The authors analyze this issue from the perspective of political science, especially within the framework of placing Poland's energy policy in the European context, but also in the technical and economic context, using an interdisciplinary approach necessary in the presentation of the state's energy balance. They also take into account aspects of the theoretical analysis of the concept of energy security. There are also discussions aimed at ensuring the country's energy security, or at least reducing the risks associated with it due to the geographical location, the need to increase Poland's energy self-sufficiency in terms of the demand for electricity produced from renewable sources and fossil fuels.

However, there are no comprehensive research treating renewable energy sources as an element of permanent sustainable development and their reference to the national and European scale, which is a response to the growing ecological and climate challenges of the modern Europe in the context of the density of transmission networks and power grid.

This paper uses the method of diagnostic survey, which understood by T. Pilch and T. Bauman (Pilch, Bauman 2001) as a way of gathering knowledge about structural and functional attributes as well as about the dynamics of social phenomena, opinions and views of selected communities, the intensification and directions of development of specific phenomena, based on a selected group in which a given phenomenon occurs. Apanowicz J. (Apanowicz 2003) notes, that the diagnostic survey method is a scientific undertaking that consists in the statistical collection of facts and information about structural and functional phenomena and the dynamics of their development. This method enables a statistical description and helps to explain certain mass phenomena. According to Łobocki M. (Łobocki 2000), the

survey method is understood as a research method whose primary function is to collect information about problems of interest to the researcher.

Multidimensional market relations: energy producers - transmission networks - final recipients, in which renewable energy development issues take a special place, contributed to the topic and prompted the formulation of this paper goals. Therefore, the main aim of the article was to assess the current state of development of renewable energy sources as a substitute of traditional sources of electricity on the background of the EU energy policy and the development of transmission networks.

After collecting and processing the source materials, it was processed using the following research methods: analysis, synthesis, confrontation and criticism of the source materials, which forms the foundations of the scientific development of the undertaken topic, exposing the essence, purpose and original tasks of the undertaken research.

Discussion

Searching for new renewable energy sources (RES) solutions began in the early 1970s as a result of the 1973 oil crisis. The research took nearly 20 years, and the outcomes became noticeable only in the 1990s. The startup period in the implementation of new technologies extended approximately over two decades (Kwinta 2014).

The environmental protection measures and the battle against climate change definitely involve funds being transferred across the globe. According to *Bloomberg New Energy Finance (BloombergNEF 2020)*, the investments in the renewable energy sector reached USD 333.6 billion in 2019 (fig. 1). According to Bloomberg data, the peak investment flow in Europe ended in 2011, reaching USD 134 billion (BloombergNEF 2020).

Nowadays, Asia-Pacific region is the leader of RES investments in the world as the economies around the world are still indisputably highly dependent on energy sources. The availability and cost of energy carriers (petroleum, coal, natural gas) are determinant for the pace of economic development at a country level. Therefore, it is of utmost importance for most countries to be able to secure the supply of energy carriers for their economies and to make sure end customers have access to energy. For example, according to recent research (Yankelovich 2006; Ostry 2010; Nyman 2018) on the US foreign policy, nearly 90% of Americans consider energy security to be a priority. It is therefore no surprise that all countries pay much attention to energy diversity and energy security.

It is crucial to ensure energy security for every country, which means diversification of energy supply, i.e. the use of a broad range of sources of energy raw materials and various types of energy, and to diversify suppliers and transport paths and mechanisms. A system based on ten to twenty large power plants is more vulnerable to sabotage than a one based on ten to twenty thousand dispersed small-to-medium capacity power stations. The risk related to the EU’s energy dependence may be reduced by establishing

reliable partnerships with suppliers, transit countries and customers. Figure 2 shows the diversification of electricity sources in EU countries grouped by energy source.

As shown in Figure 2, Poland is the EU's fourth largest consumer of fossil fuels (mainly coal) used for electricity generation. The Polish energy sector has always been based on coal and lignite, and therefore the largest power generation units were located near coal and lignite mines.

According to the Energy Market Agency and to PSE S.A. data, the share of coal in the energy source mix decreased from 62% in 1996 to 49,27 % in 2019 (2020b). However, coal remains the main source of electricity in Poland, as shown in Figure 3.

According to the "Polish energy policy to 2030" and "Program for the hard coal mining sector in Poland" coal will remain the basic raw material for the electric power sector (Ministry of Economy 2009; Ministry of Energy 2018), even though the extraction capacity declines and the mines lack funds to access new deposits. Also, the market offers large quantities of cheap imported coal. Combined with the poor performance and underinvestment of Polish mines, this results in a slowdown affecting the electricity sector (Wroński 2015).

The energy networks are underdeveloped, especially in the current situation of abovementioned conditions. The reason for this is the fact that the transmission and distribution networks were neither expanded nor upgraded since the 1970s and the network infrastructure (Figure 5) is not aligned with the changing location and structure of electricity demand and production. All abovementioned circumstances results, for instance, in blocking the access to electricity from wind and biogas power plants and developing the distributed generation. As a consequence, according to some forecasts, by 2030, ca. 60% of electricity will be produced from coal while the share of RES will be ca. 20%, as shown in Figure 4.

Results

While analyzing the density of the Polish electricity grid (Fig. 5), it would be useful to make a reference to the condition of the grid in some European countries. In accordance with 2009 data (Fig. 5), Poland ranked second-worst (Stankowska 2009), followed only by Hungary, in terms of infrastructure density of highest-voltage transmission lines, with 41 km per 1000 km^2.

When comparing the density of electricity grids between Poland and other European countries (Figure 7), the difference is clearly noticeable. As mentioned earlier, Poland has one of the Europe's lowest infrastructure densities of highest-voltage transmission lines.

Especially during summer period, electricity demand largely exceeds the average level, particularly in major agglomerations. Many networks in these areas have already reached their operational limits and must be extended and upgraded (Wasiuta 2014). Therefore, firm conclusions can be drawn regarding the extent of required investment projects in Poland.

In Polish economy, the demand for hard coal is partially fulfilled with imports, and that trend is forecasted to continue. In 2017, coal imports into Poland was 13,3 million tons which is 18% of total consumption. By the end of 2019, 16,7 million tons of coal were imported into Poland, which is 24% of total consumption (Statistics Poland (GUS) 2020).

In Poland, steam coal accounted for most of the imports. The largest quantities (61% of total imports) were imported into Poland from Russia, followed by Australia with 19.2% (although it was coking coal only); 8.6% of total coal imports originated from the USA and Columbia (EUROSTAT 2020b).

The problem of lignite extraction is also discussed intensively, mainly with the environmentalist community, because it has a strong environmental impact (Wojnowski 2002). For the energy sector and the coke industry, it would be impossible to switch exclusively to Polish raw materials because some types of coal are not extracted in Poland (Wasiuta 2014). Compared to neighboring countries, Poland has relatively large coal resources, documented natural gas reserves, shale gas, Europe's largest geothermal reservoirs. Among the non-biomass renewable options, wind power has the largest potential in Poland. The main challenges to its development are the limited number of locations with high wind speed. Offshore offers better wind speed than onshore, but its costs are twice as high (Waydel 2008; Gielen et al. 2015).

Nuclear power plants are a controversial source of energy for the society and a potential target for hackers, and therefore involve the issues of national security. Nevertheless, it can be pointed out the low carbon emission aspect of nuclear energy (Johnson 2009). Having the above in mind, according to different calculations, wind energy, for instance offshore wind energy at the Baltic sea, could be a substitute for nuclear energy in Poland (2012; Kowalczyk 2019). In this context, the diversification of energy sources is a fundamental aspect of managing the risks to secure supplies of energy raw materials to any country. Renewable energy sources could play a major role in this process. The production of electricity from renewable sources, and especially distributed generation production cannot be perturbed by foreign governments or other national or international organizations; this is an essential aspect for the country's energy security.

Though more expensive, cogeneration is more environmentally friendly and consists in the simultaneous production of electricity and heat used in industrial processes, building heating and water heating. It results in saving conventional sources and reducing carbon emissions, as promoted under the relevant EU Directive (European Parliament 2012). Cogeneration is crucial for the national energy security. The European Union pays particular attention to promoting this technology by emphasizing not only its energy efficiency but also the ability to considerably reduce the emissions of carbon dioxide and other harmful chemicals. While this technology attracts interest from the coal and gas industries, it may also be combined with renewable energy sources. Undoubtedly, such a solution contributes to reducing the use of conventional fuel in electricity and heat production processes.

The greater use of primary energy contained in fuel in the simultaneous production of electricity and heat contributes to improvements in energy efficiency. This is the key advantage of this system: energy

efficiency may be up to 30% higher compared to separate generation of both types of energy in condensing power plants (electricity) and boiler stations (heat). Cogeneration plants provide heat and power 50 -70% more efficiently than traditional facilities. Observation of technological processes shows that a cogeneration system uses 100 fuel units to produce 40 units of electricity and 50 units of heat whereas a total of 170 fuel units are required to produce the same amounts of energy in separate processes (Buczyńska 2015; Schleup 2008).

However, real benefits can be attained through the use of renewable energy sources. If used instead of conventional fuels, they contribute to a further reduction in carbon emissions. In cogeneration, renewable energy sources mainly mean the use of biomass. Ingredients used to cogenerate heat and electricity include: farm waste, waste food, plants and waste wood. In broad terms, biomass also means biogas which is produced with the use of manure or in waste treatment plants. The greatest shares of biomass used in cogeneration systems are reported in Sweden and New Zealand, i.e. countries with the largest forestry and wood industries (Buczyńska 2015).

In Poland, total electricity production from high-efficiency cogeneration did not change much over the 2007–2017 period. At the end of 2007, it was 159,348 GWh, representing ca. 17.5% of electricity production. The corresponding figures at the end of 2017 were 16.72% respectively (Central Statistical Office 2020).

The key advantages of cogeneration schemes include: reduced fuel consumption per energy unit; reduced emissions of pollutants; reduced heat losses in transmission networks; dispersion of energy sources; and creation of new local jobs.

The Polish Energy Law (Ministerstwo gospodarki 1997) provided for certain forms of support for cogeneration. Note that the Regulation of the Minister of Economy of December 15, 2000 (issued with the participation of the Department of Energy) on the obligation to purchase electricity from non-conventional and renewable sources of energy, electricity cogenerated with heat and heat from non-conventional and renewable sources, and laying down the extent of this obligation (Journal of Laws 2000) was only relevant to large energy undertakings while providing little help to small companies. The Regulation of the Minister of Economy, Labor and Social Policy concerning detailed scope of the obligation to purchase electricity and heat from renewable sources of energy and electricity cogenerated with heat (Journal of Laws 2003) entered into force in 2003. In accordance with these assumptions, the obligation to purchase renewable energy was introduced.

The adoption of the Act on Renewable Energy Sources (Sejm of the Republic of Poland 2015b) was followed by many changes. For the first time in Poland, feed-in tariffs were introduced which specify the principles for the sale of energy by the smallest RES micro-installations to the grid.

Because of the fact, that the support mechanism for high-efficiency cogeneration expired at the end of 2018, the Ministry of Energy prepared a draft Act on Promoting Electricity from High-Efficiency Cogeneration (2018) providing for a new support mechanism for the producers of energy from

cogeneration installations. By the end of 2019 the law was adopted and entered into force (Sejm of the Republic of Poland 2019). The introduction and implementation of these changes is an important element in the fight against high levels of pollutants and greenhouse gases in Poland. In addition to cogeneration, tri-generation becomes increasingly important, especially in Germany (because of the availability of the technology). This means using the same technological process to generate heat, electricity and cooling energy in order to reduce the amount and cost of primary energy required to produce each of these energies separately (Gailfuß 2019).

Heat, cooling energy and electricity are three totally different products subject to different laws. While the market for heat and cooling energy is of a purely local nature, electric power is sold across a wide territory (on a countrywide and Union-wide basis). Ecological arguments and the strategic importance of cogeneration and tri-generation, mainly due to improvements in the efficiency of primary fuel consumption through the use of heat, are the reasons why efforts are being made to introduce stronger economic incentives and legal frameworks supporting the use of these solutions. The cogeneration policy results from the EU climate policy. To meet the objective of reduced carbon emissions, it is necessary to considerably reduce heating-related emissions.

Self-sufficiency means not only secure supplies of energy to end customers from external and internal suppliers but also the internal operational security of the entire energy sector. In Poland, it is threatened by many factors, such as miners' strikes, the deplorable condition of transmission networks, as reflected by numerous network failures and measures taken by monopolists who do offer certain products to end customers but charge extremely high prices. These threats may be qualified as socio-political, technical and economic aspects. However, the customer does not care about the reasons behind a disruption in energy or fuel supply. Some countries, e.g. the US, Italy or Japan, are not energy self-sufficient but feel secure. This is because their national energy policies address various dimensions: efficiency (in Japan), diversification (Italy and US) and adequate foreign policy, especially alliances (in Japan and US). Equating energy security with self-sufficiency may result in an attempt to build a country which does not need any external relationships. This would be unviable, as illustrated by the example of North Korea (2007). However, the above does not mean that Poland should refrain from seeking a greater degree of self-sufficiency in industries which rely on other countries, i.e. the gas and liquid fuels industries.

The development of renewable energy sources is among the key objectives of the Polish energy policy. The draft "Energy policy for Poland to 2050" (Ministry of Energy 2015a) developed by the Ministry of Economy includes a long-term development strategy for the energy sector, a forecast of fuel and energy demand and an implementation program. Also, it clearly indicates the development of RES to be a strategic objective (Ministry of Energy 2015b). The document defines priority lines of action, such as: improvements in energy efficiency; increased security of fuel and energy supply; diversification of electricity production (through the introduction of nuclear energy); greater use of renewable energy sources, including biofuel; development of competitive markets for fuel and energy; and reduced environmental impact of the energy sector. The Minister of Economy monitors the ongoing progress in policy implementation. Also, an interministerial team in charge of national raw material policy (Poland

2012) has been in place since 2016. The key role of RES in the development of the Polish energy sector is also reflected by the adoption of the long awaited Act on Renewable Energy Sources (Sejm of the Republic of Poland 2015a).

The key lines of development for the energy policy are as follows (Ministry of Economy 2009): improvements in energy efficiency; increased security of fuel and energy supply; diversification of the electricity production mix through the introduction of nuclear energy; extended use of renewable energy sources, including biofuel; development of competitive markets for fuel and energy; reduced environmental impact of the energy sector. The defined energy policy orientations are largely interdependent. The improvements in energy efficiency reduce the increase in demand for fuel and energy. This contributes to energy security by making the country less dependent on imports while also helping reduce emissions and the resulting environmental impact of the energy sector. Similar effects can be achieved by promoting a greater use of renewable energy sources, including biofuel, clean coal technologies and nuclear energy.

To comply with European Union obligations, Poland as well as all EU countries, is required to reach the share of energy from renewable energy sources in EU's gross final consumption of energy in 2030 which is 32% (European Parliament 2018). Every country will also be committed to a greater integration of renewable energy sources into the energy system, for increasing flexibility of the energy system and maintaining grid stability, developing transmission and distribution grid infrastructure and intelligent networks. It should be also noted, that initially much was expected from the use of biofuels and bioliquids, including a reduction in transport carbon emissions and freeing the country from dependence on fossil fuel supplies from abroad. However, in reality, the situation proved to be much more complicated. The European Union issued two Directives which require the member states to attain specific levels of biofuel use in transport. For the calculation of a Member State's gross final consumption of energy from renewable energy sources and the minimum share of biofuels and bioliquids consumed in transport, where produced from food and feed crops, shall be no more than one percentage point higher than the share of such fuels in the final consumption of energy in the road and rail transport sectors in 2020 in that Member State, with a maximum 7% of final consumption of energy in the road and rail transport sectors. As a consequence of this policy, large areas under existing crops started to be converted to biofuel feedstock production. At the same time, to meet the growing demand for food, it was necessary to establish new agricultural areas. This is done through deforestation and destruction of peatland and other valuable habitats which naturally store carbon and reduce atmospheric carbon emissions. The above is referred to as Indirect Land Use Change (ILUC) (Bhatia 2014; European Commission 2017; Lapola et al. 2010).

According to assumptions of the "Polish energy policy to 2030," support mechanisms for RES development in Poland need to be strengthened; improvements should be made to the investment climate; new, more effective economic instruments should be deployed to provide a momentum for RES investments and for the production of RES-based technologies while also maximizing the absorption of European funds, mainly under the Regional Operational Programs, Rural Development Program and the

Infrastructure and Environment Operational Program, allocated to such projects as: production of renewable energies together with the connection to the distribution/transmission network (hydropower, wind, solar, geothermal, biogas and biomass energy); construction and reconstruction of networks enabling the connection of renewable electricity to the National Electricity System; construction of installations for biofuel and its components.

Even though the relevant act was adopted, the development of RES in Poland continues to face many problems. The uncertainty surrounding the regulations and the absence of support for the development of a dispersed RES system are the main barriers to the development of this sector in Poland. According to the “Polish renewable energy machinery industry: updated business directory and assessment of development opportunities for the industry in the 2020 and 2030 time horizon,” (Wiśniewski et al. 2016) a report by the Institute for Renewable Energy, the absence of a consistent support policy for the Polish RES industry may result in halting its development and losing measurable benefits. It has already become apparent that some industries of this sector face an uncertain future. For instance, solar energy companies are doing somewhat better but without adequate incentives from the government they, too, may stop developing. Currently, as many as 33,800 people are employed in the RES industry. According to the “energy revolution” (2013) scenario developed by the Institute of Renewable Energy in 2013, over 100,000 people could be employed in the Polish RES industry in 2030, i.e. as many as in the entire apparel industry in 2018 (Wiśniewski et al. 2016; Statistical Publishing Establishment 2019). In 2016, the number of employees in the RES industry in Poland and in the EU was 43,300 and 1,139,050, respectively (Wasiuta 2018). In turn, according to a report by IRENA, there were 9.8 million people employed in the RES industry around the world in 2016, most of them (over 3.8 million) in China, the leader of renewable energies. The European Union ranked second with nearly 1.2 million RES jobs; Germany and France had the largest share (334 thousand and 162 thousand, respectively) . Note also that EU enterprises own 40% of all patents for renewable technologies (Tomaszewski 2018).

According to experts from the Institute for Renewable Energy, the Polish industry of solar energy equipment alone may contribute a total of PLN 18.5 billion to the budget in 2015–2030. However, this cannot be done without a stable legislation and a long-term policy which provide support for dispersed RES systems .

A stable and socially equitable support system is a necessary condition for the development of the Polish RES sector, especially including the most promising small and micro-installation segment. Feed-in tariffs are the most effective support instrument for the development of the RES sub-sector specialized in the manufacture of power generation equipment. The benefits of this system are the predictability and simplicity of support. It is also crucial that support has to be provided mostly for dispersed investments in small and micro-sources to encourage the development of local companies and prosumers. In order for renewable energy companies to develop, the equipment manufacturing sector must be included in official statistics on the RES sector (which currently are not kept) . The amendment to the RES Act extends the support for RES development by combining feed-in tariffs with a system of rebates (Article 4 of the RES

Act (Sejm of the Republic of Poland 2015b)) which enables cashless settlement of payments for electricity used by prosumers and produced in a micro-installation.

So far, the Polish RES industry has the longest track record in the production of solar collectors, biomass boilers and heat pumps. Each year in Poland, specialized companies sell and install equipment worth PLN 2 billion. A steep decline in multiannual support programs for RES-based heat production and the promotion of coal as a local fuel are barriers to the development of these traditionally strongest companies of the Polish RES industry and make it impossible to offset losses incurred domestically with exports (Sejm of the Republic of Poland 2015b).

By leveraging market mechanisms, the Energy Efficiency Act introduces a series of measures, including the system of energy performance certificates – so called “white certificates”, which should drive measurable energy savings in three areas: increased energy savings for end customers; increased energy savings in personal equipment; and reduced electricity, heat and natural gas losses across the industry and in distribution networks. B2C energy suppliers are required to receive and submit “white certificates” for redemption to the President of the Energy Regulatory Office. Otherwise, they must pay a compensation fee. Electricity, natural gas and heat suppliers are required to obtain a specific number of certificates depending on the amount of energy sold.

Although the households keep improving their energy efficiency ratios, energy demand in this sector is estimated to grow until 2030. While total energy consumption will increase only slightly (by ca. 5%), the increase in the consumption of one of its components (electricity) will grow by as much as 50%. Electricity production uses the greatest amounts of primary energy, and therefore electricity savings are potentially most beneficial to the environment. Since early 2000s, Poland has witnessed tremendous improvements in energy efficiency. Indeed, the energy intensity of Gross Domestic Product decreased by nearly one third. However, energy efficiency of the Polish economy is three times lower compared to the most developed European countries and approximately two times lower than the EU average level. Also, primary energy use per capita in Poland is almost 40% lower than in the“old 15” EU countries. This suggests there is a great potential for energy savings in Poland, which is a characteristic of economies experiencing rapid growth (Ministerstwo Infrastruktury i Rozwoju 2014).

Households use ca. 20% of electricity consumed in Poland (Maj 2015), and have the greatest impact on consumption growth rates. The potential for savings seems considerable, yet not adequately used. Therefore, the question could be explored whether households should be provided with greater support in the area of electricity savings.

Conclusions

The development of low-carbon energies which is an economically strategic sector of science, engineering and technology, depends on significant improvements to its development conditions. With reference to the essential objective of the European Union Directive on renewable and low-carbon forms of energy generation, it may be concluded that no single organizational solution and no single technology

exists that could meet the demands and expectations of all parties. Optimum solutions must be sought in specific locations (using primarily combined heat and power) and specific macroeconomic and regional environments. Ensuring the conditions for a contribution to the development of renewable energies in Poland is a challenge to the government. The energy sector should evolve in a direction consistent with measures taken by the European Union and with initiatives taken by local authorities.

However, despite the great opportunities behind the use of renewable energies, their average share in the general energy mix of European Union countries is expected to be only 32% by 2030. Perhaps it will rise to 50% by 2050. Therefore, while having no other option than to continue relying on coal, oil and gas and nuclear energy in some countries, European Union must be aware of the consequences of the continued use of these energy carriers. An increased use of renewable energies should neither make EU less vigilant to energy security nor release it from responsibility for future generations.

Declarations

Ethics declarations

Ethical approval and consent to participate - Not applicable.

Consent for publication - Not applicable.

Competing interests - Not applicable.

References

1. Apanowicz J. (2003). Metodologia ogólna. Bernardinum, Gdynia
2. Bhatia, S. C. (2014). *Advanced renewable energy systems.* Woodhead Publishing India in energy. New Delhi: Woodhead Publishing India PVT Ltd. (2007). Biznes +. *Gazeta Prawna*(21).
3. BloombergNEF (2020). *Clean Energy Investment Trends, 1H 2020*.
4. Buczyńska, E. (2015). Kogeneracja. Czym jest i jakie stwarza możliwości? (The meaning of and opportunities behind cogeneration). https://swiatoze.pl/kogeneracja-czym-stwarza-mozliwosci/. Accessed 14 November 2020.
5. Central Statistical Office (2020). *Energy 2020.* Warsaw. (2013). *Energy [r]evolution: A sustainable Poland energy outlook*.
6. European Commission (2017). Land use change. https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/land-use-change. Accessed 12 July 2017.
7. European Parliament (2012). *Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance*.
8. European Parliament (2018). *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (Text*

with EEA relevance.): PE/48/2018/REV/1.

9. EUROSTAT (2020a). Net electricity generation by type of fuel - monthly data. Accessed 12 November 2020.
10. EUROSTAT (2020b). Shedding light on energy on the EU: From where do we import energy and how dependent are we? https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-2c.html. Accessed 13 November 2020.
11. Gailfuß, M. (2019). Grundlagen der Kraft-Wärme-Kälte-Kopplung. https://www.bhkw-infozentrum.de/allgemeine-erlaeuterungen-bhkw-kwk/kwkk-grundlagen.html. Accessed 17 July 2019.
12. Gielen, D., Saygin, D., & Wagner, N. (2015). *REmap 2030: Renewable Energy Prospects for Poland.* Abu Dhabi. (2020a). Grid Map. https://www.entsoe.eu/data/map/. Accessed 4 December 2020.
13. Johnson, K. (2009). Is Nuclear Power Renewable Energy? *The Wall Street Journal*.
14. Journal of Laws (2000). *Regulation of the Minister of Economy of December 15, 2000 on the obligation to purchase electricity from unconventional and renewable sources, as well as electricity generated in combination with the production of heat, as well as heat from unconventional and renewable sources, and the scope of this obligation.*, vol. 122.
15. Journal of Laws (2003). *Regulation of the Minister of Economy, Labor and Social Policy of May 30, 2003 on the detailed scope of the obligation to purchase electricity and heat from renewable energy sources and electricity generated in combination with the production of heat*, vol. 104.
16. Kowalczyk, J. (2019). Perspektywy rozwoju energetyki jądrowej w unijnym otoczeniu polityczno-regulacyjnym. *Elektroenergetyka: współczesność i rozwój, 1(20)*, 6–17.
17. Kwinta, W. (2014). Energetyka — brakujące ogniwo (paliwowe)? Za wcześnie, by obwieścić triumf (The energy sector: The missing link or the missing fuel cell? Still waiting for success). *Energia Gigawat, 2014*.
18. Lapola, D. M., Schaldach, R., Alcamo, J., Bondeau, A., Koch, J., Koelking, C., et al. (2010). Indirect land-use changes can overcome carbon savings from biofuels in Brazil. *Proceedings of the National Academy of Sciences of the United States of America, 107*(8), 3388–3393.
19. Łobocki M. (2000). *Metody i techniki badań pedagogicznych*. Oficyna wydawnicza Impuls, Kraków
20. Maj, R. (2015). *Efektywność energetyczna w gospodarstwie domowym jest niedoceniana czy przeceniana? Analiza na przykładzie zużycia energii elektrycznej.* Warszawa: Wydawnictwo Pracodawcy Rzeczypospolitej Polskiej.
21. Ministerstwo gospodarki (1997). *Ustawa z dnia 10 kwietnia 1997 r. - Prawo energetyczne*.
22. Ministerstwo Infrastruktury i Rozwoju (2014). *Programowanie perspektywy finansowej 2014–2020: Umowa Partnerstwa.* Warszawa.
23. Ministry of Economy (2009). *Polish energy policy to 2030*.
24. Ministry of Energy (2015a). Draft „Energy Policy of Poland until 2050”. https://www.gov.pl. Accessed 22 December 2017.

25. Ministry of Energy (2015b). Implementation program. Appendix 3 to the “Polish energy policy to 2050.
26. Ministry of Energy (2018). *Program dla sektora górnictwa węgla kamiennego w Polsce.* Warszawa.
27. Ministry of Energy (2019). *Polityka energetyczna Polski do 2040 r. [Poland's energy policy untill 2040]: Załącznik 2. Wnioski z analiz prognostycznych dla sektora paliwowo-energetycznego [Annex 2. Conclusions from forecast analyzes for the fuesl and energy secor].* Warsaw. (2012). Nuclear energy. *Ratujmy świat, 12*.
28. Nyman, J. (2018). *The Energy Security Paradox: Rethinking Energy (In)security in the United States and China:* Oxford University Publisher.
29. Ostry, S. (Ed.) (2010). *Sustainable Development and Energy Security: The WTO and the Energy Charter Treaty*. Pre-G8 Conference.
30. Pilch T., Bauman T., 2001, *Zasady badań pedagogicznych*. Wydawnictwo akademickie Żak, Warszawa
31. Poland, S. o. t. R. o. (2012). *Act of August 8, 1996 on the Council of Ministers: Journal of Laws of 2012, item 392 and of 2015, item 1064*.
32. Polish Transmission System Operator (2020). Scheme of the extra high voltage power grid. https://www.pse.pl/web/pse-eng/areas-of-activity/polish-power-system/scheme-of-the-extra-high-voltage-power-grid. Accessed 13 November 2020.
33. Polskie firmy OZE czeka upadek. https://www.greenpeace.org/archive-poland/pl/wydarzenia/polska/Polskie-firmy-OZE-czeka-upadek/. Accessed 18 July 2019. (2020b). Raport 2019 KSE: Zestawienie danych ilościowych dotyczących funkcjonowania KSE w 2019 roku. https://www.pse.pl/dane-systemowe/funkcjonowanie-rb/raporty-roczne-z-funkcjonowania-kse-za-rok/raporty-za-rok-2019. Accessed 12 November 2020.
34. Renewable Energy and Jobs – Annual Review 2017. https://www.irena.org/publications/2017/May/Renewable-Energy-and-Jobs–Annual-Review-2017. Accessed 17 July 2019.
35. Renewable energy sources in the 2014–2020 time horizon. http://www.funduszeeuropejskie.gov.pl/strony/wiadomosci/odnawialne-zrodla-energii-w-perspektywie-2014-2020. Accessed 17 July 2019.
36. Schleup, J. (2008). How Does Cogeneration Provide Heat and Power? https://www.scientificamerican.com/article/how-does-cogeneration-provide-heat-power/. Accessed 14 November 2020.
37. Sejm of the Republic of Poland (2015a). *Act on Renewable Energy Sources: Journal of Laws of 2015, item 478*.
38. Sejm of the Republic of Poland (2015b). *Act on Renewable Energy Sources: Journal of Laws of 2015, item 478*.
39. Sejm of the Republic of Poland (2019). *Act on Promoting Electricity from High-Efficiency Cogeneration: Journal of Laws of 2019, item 42*.

40. Stankowska, A. (2009). Implementation of electric power line investments. *Elektroenergetyka*(1), 34–39.
41. Statistical Publishing Establishment (2019). *Yearbook of Labor Statistics 2019.* Warszawa.
42. Statistics Poland (GUS) (2020). *Energy 2020*. (2018). The Ministry of Economy is launching a consultation on the draft Act on Promoting Electricity from High-Efficiency Cogeneration. https://www.gov.pl/web/energia/me-rozpoczyna-konsultacje-projektu-ustawy-o-promowaniu-energii-elektrycznej-z-wysokosprawnej-kogeneracji. Accessed 17 July 2019.
43. Tomaszewski, K. (2018). Energy policy of the European Union in the context of economic security issues. *Przegląd Politologiczny*(1), 133.
44. *Ustawa z dnia 20 maja 2016 r. o efektywności energetycznej: (Dz.U. 2016 poz. 831)*.
45. Wasiuta, A. (2014). *Ekonomiczne uwarunkowania rozwoju energetyki wiatrowej (Economic prerequisites for the development of the wind power sector).* Warsaw: Publishing House of the Faculty of Journalism and Political Science, University of Warsaw.
46. Wasiuta, A. (2018). Labor market in Poland in the context of renewable energy sector development. *Economics and environment, 1*(64).
47. Waydel, P. (2008). How to make the country energy secure. http://www.drewnozamiastbenzyny.pl/jak-zapewnic-bezpieczenstwo-energetyczne-kraju/. Accessed 17 July 2019.
48. Wiśniewski, G., Więcka, A., Bolesta, J., & Czajka, P. (Eds.) (2016). *Polski przemysł produkcji urządzeń dla energetyki odnawialnej — aktualizacja bazy danych firm i ocena możliwości rozwoju branży do 2020 i do 2030 roku.* Warszawa.
49. Wojnowski, J. (Ed.) (2002). *Great Encyclopedia of the PWN*, 1st edn. Warsaw: PWN Scientific Publishing House.
50. Wroński, M. (2015). Górnictwo: jest źle, a będzie jeszcze gorzej. Branża nie ma wątpliwości (The mining sector: the situation is already bad and will deteriorate further. Industry representatives are firm). https://dziennikzachodni.pl/gornictwo-jest-zle-a-bedzie-jeszcze-gorzej-branza-nie-ma-watpliwosci/ar/c3-10207172. Accessed 20 January 2020.
51. Yankelovich, D. (2006). The Tipping Points. *Foreign Affairs*, 115–126.

Figures

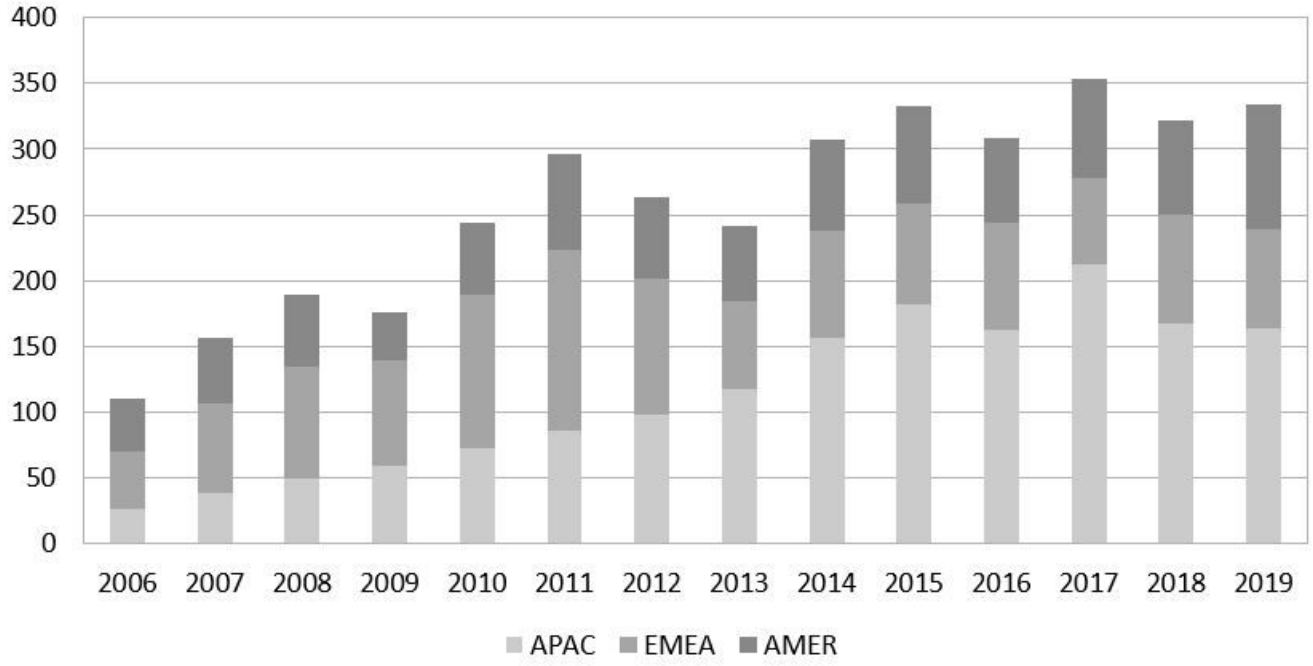

Figure 1

Global new investment in renewable energy sources (by region) Source: (BloombergNEF 2020)

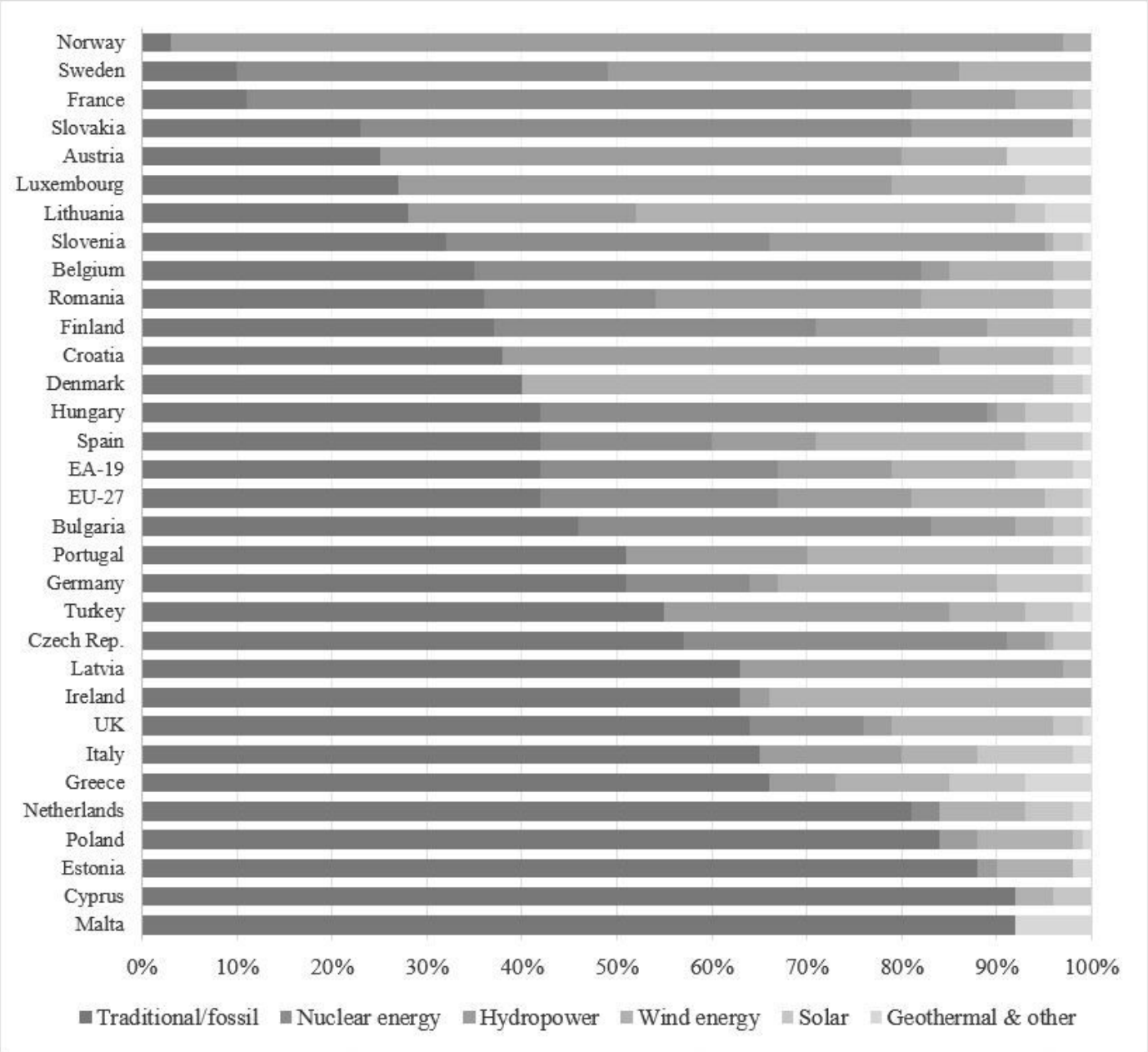

Figure 2

Electricity production mix in the EU in 2019 Source: based on (EUROSTAT 2020a)

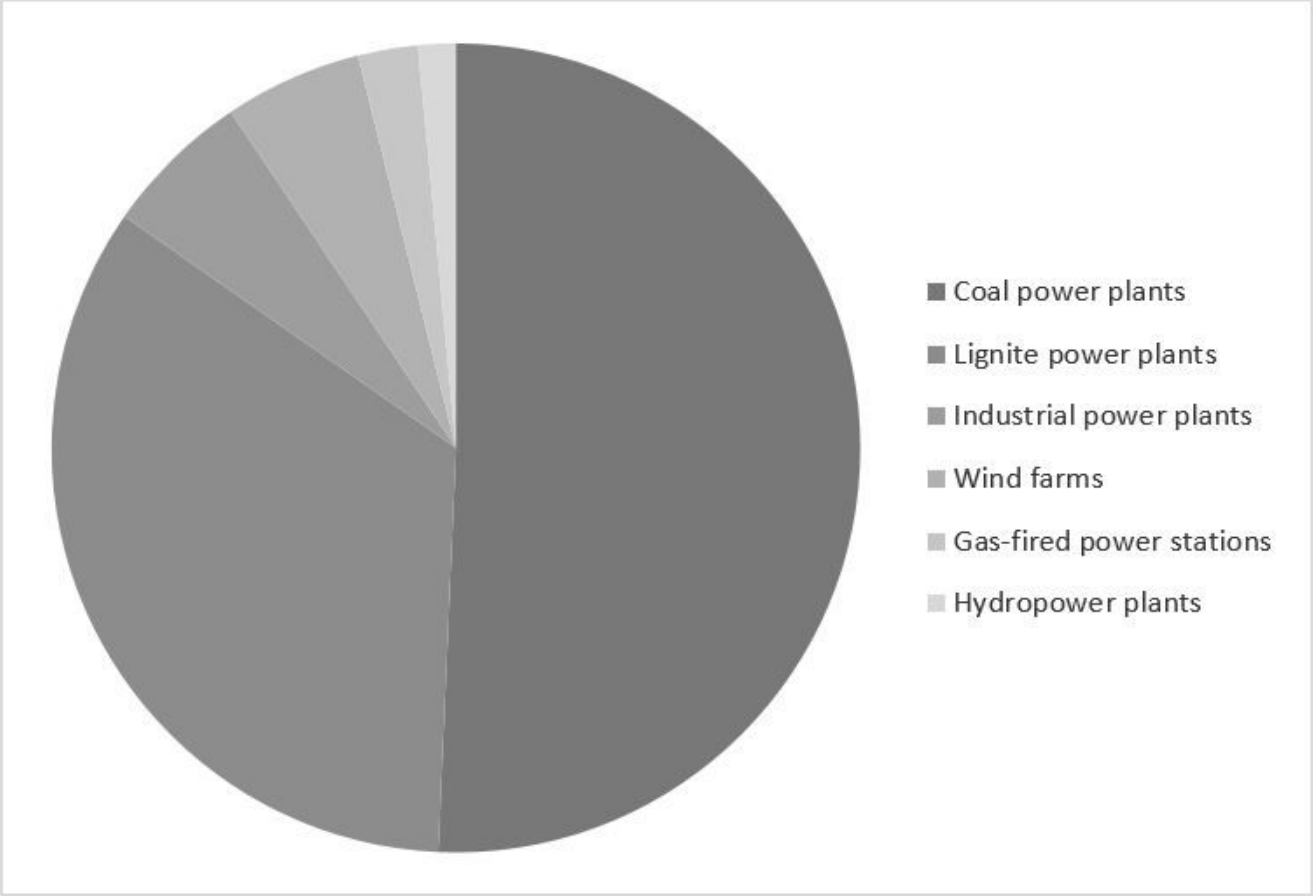

Figure 3

Electricity production mix in Poland in 2015 Source: (2020b)

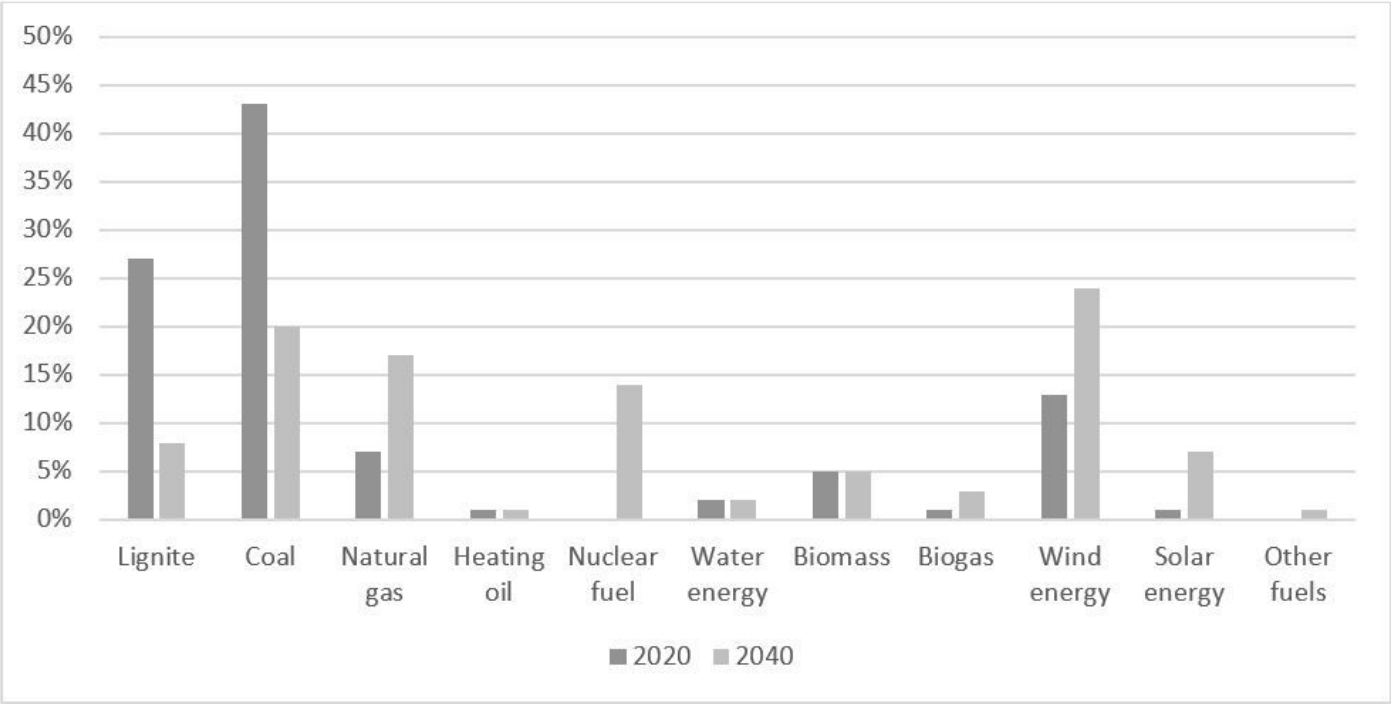

Figure 4

Comparison and forecast of gross electricity production in Poland in 2020 and 2040, by source Source: own study based on (Ministry of Energy 2019)

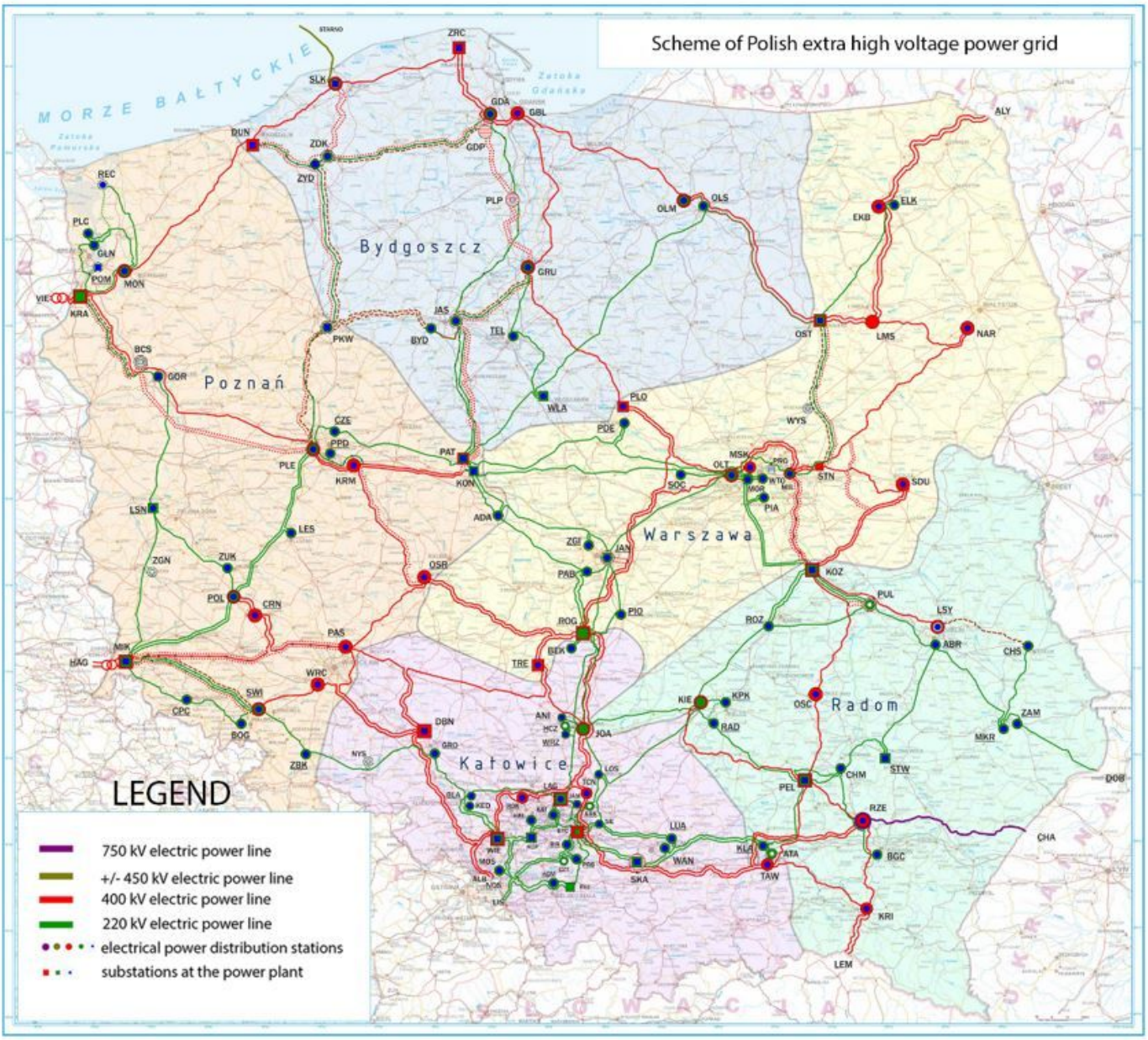

Figure 5

Scheme of Polish extra high voltage power grid (as of October 31, 2018) Source: (Polish Transmission System Operator 2020) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

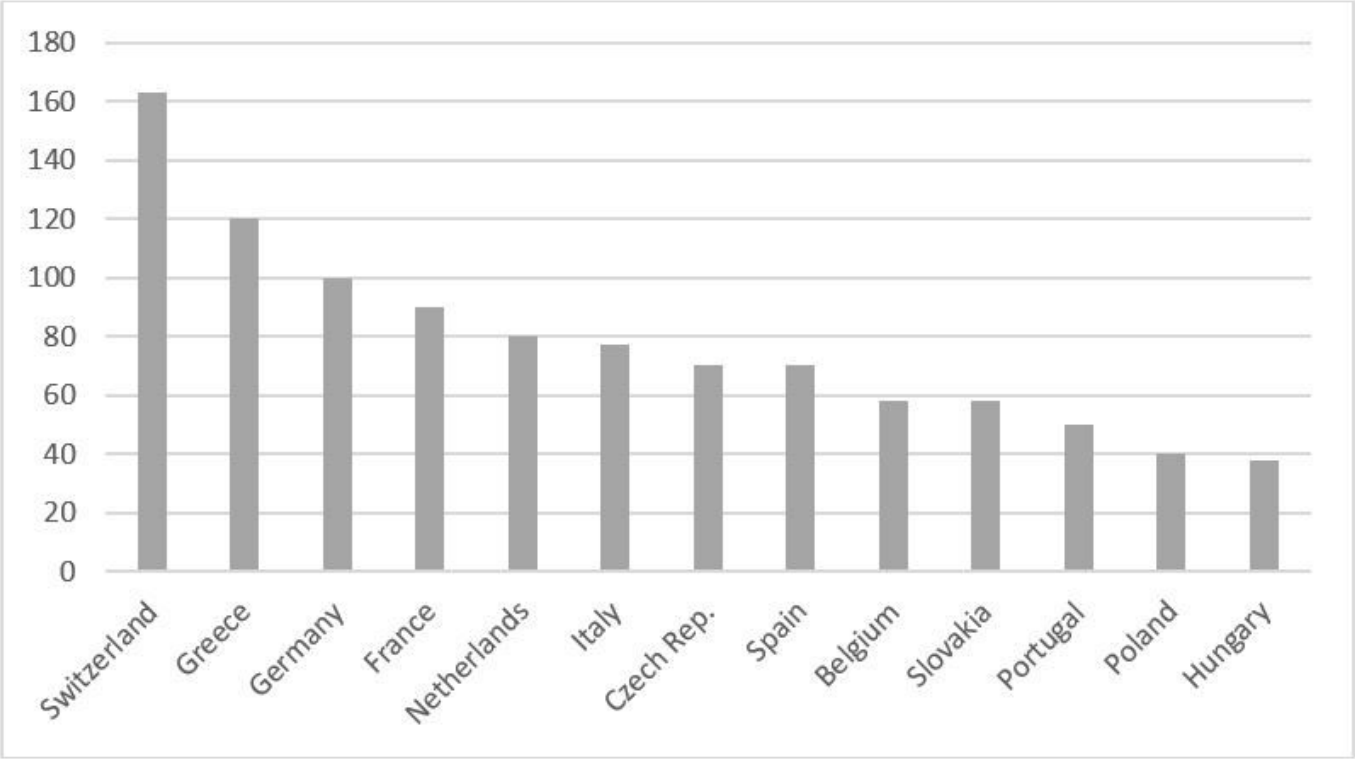

Figure 6

Total length of 220 kV and 400 kV transmission lines per 1000 m2 of national territory Source: (Stankowska 2009)

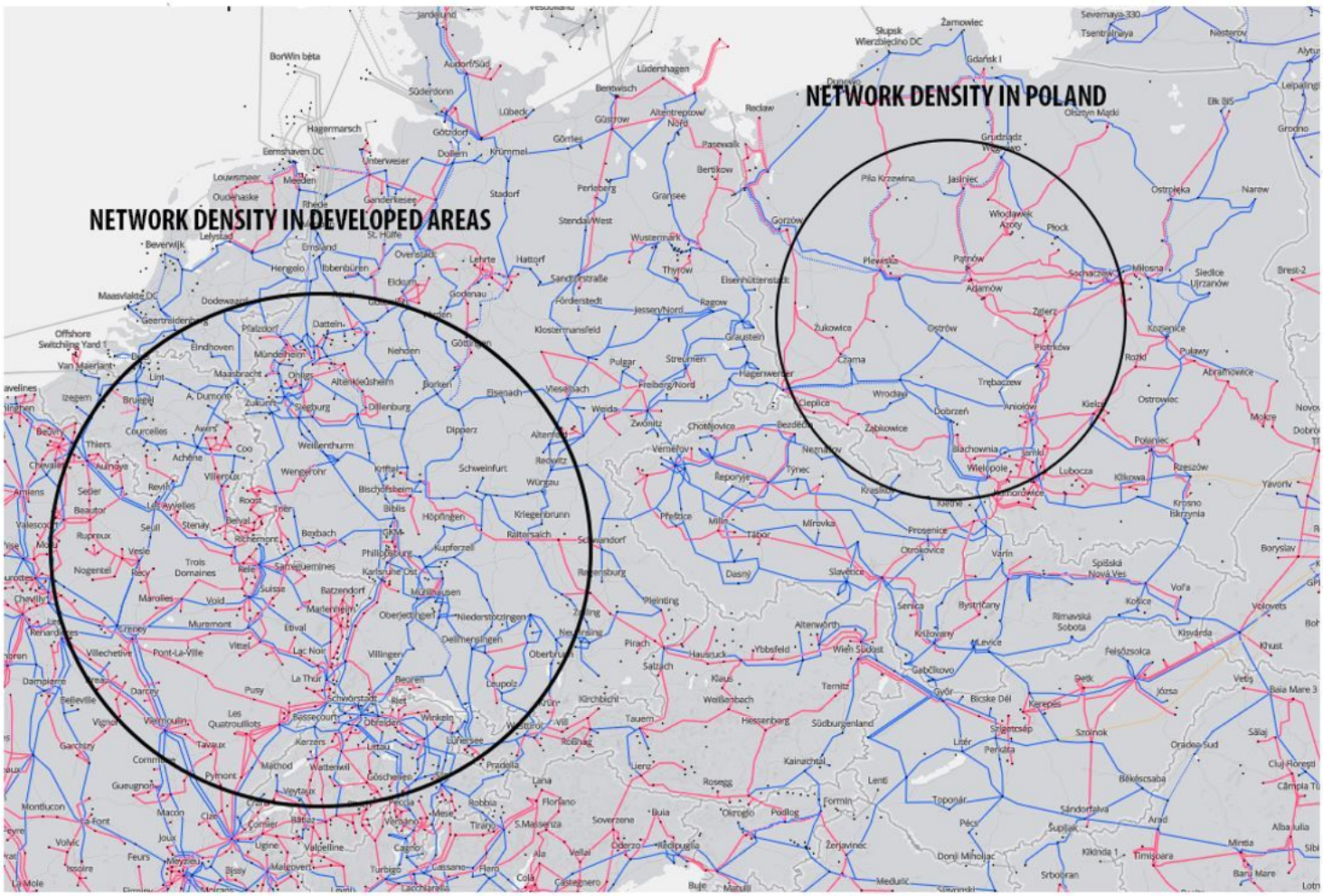

Figure 7

Layout of transmission networks in Europe Source: (2020a) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.