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RISKS RELATED TO ENERGY POLICY OF POLAND UNTIL 2040 (EPP 2040)

The paper presents a brief outline of the European Union Climate and Energy Package in early 2020, as well as the EU's plans in this respect until 2030 (Winter Package and Green Deal) and even further until 2050 (EU's climate neutral target). Also the current condition of power generation in Poland and challenges for Polish energy sector in the nearest future are discussed. The Energy Policy of Poland until 2040 (EPP 2040) is analysed in relation to possible risks and dangers. Some improvements are proposed in regard to the implementation of the document. In addition, the current volume and perspectives of hard coal and lignite mining in Poland until 2040 are discussed and compared with an expected demand for coal in Polish power plants and combined heat and power stations. On the basis of the prognosis of energy consumption in the period 2031-2040, there seems to appear a serious risk of energy shortage due to a possible delay in a nuclear power project and lack of lignite mining at the level defined in EPP 2040 policy. Therefore, some variants of providing the security of energy supplies are taken into account and thoroughly analysed in the paper.

Keywords: lignite, hard coal, power engineering, efficiency of electricity generation, emission reduction

1. European climate and energy policy in early 2020

The beginning of 2020 has brought about, at least in a political sphere, a rather unexpected acceleration of transformation tempo of the European economy towards its climate neutrality. This is a clear consequence of the European Council's conclusions published on the 12th of December 2019, in which the Member State leaders unanimously resolved the following:

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"*In the light of the latest available science and of the need to step up global climate action, the European Council endorses the objective of achieving a climate-neutral EU by 2050, in line with the objectives of the Paris Agreement. One Member State, at this stage, cannot commit to implement this objective as far as it is concerned, and the European Council will come back to this in June 2020.*" [Conclusions, 2019].

It is noteworthy that such an ambitious resolution was adopted only half a year after rejecting a climate-neutral target by the previous European Council. In fact, on 20th of June 2019 the Council "only" confirmed the continuation of "building on the measures already agreed to achieve the 2030 reduction target." [Conclusions, 2019].

A climate neutrality of the entire European economy by 2050 should be understood as achieving such its condition that the total sum of greenhouse gases emission to the atmosphere is balanced with the absorption processes by forests and with carbon capture storage and utilisation (CCSU) technologies. The climate-neutral target was presented for the first time during the climate summit in Katowice (Poland) in December 2018 by the EU's climate and energy commissioner M. Cañete in the document "A Clean Planet for All. A European Strategic Long-term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy" [Clean Planet, 2018]. Figure 1 presents the necessary decrease of greenhouse gases emission by 2050 to reduce the increase of the Earth's temperature by 1.5°C. In 2050, the sum of remaining emissions from transport, agriculture and other sectors of economy will be balanced by absorption and CCSU technologies.

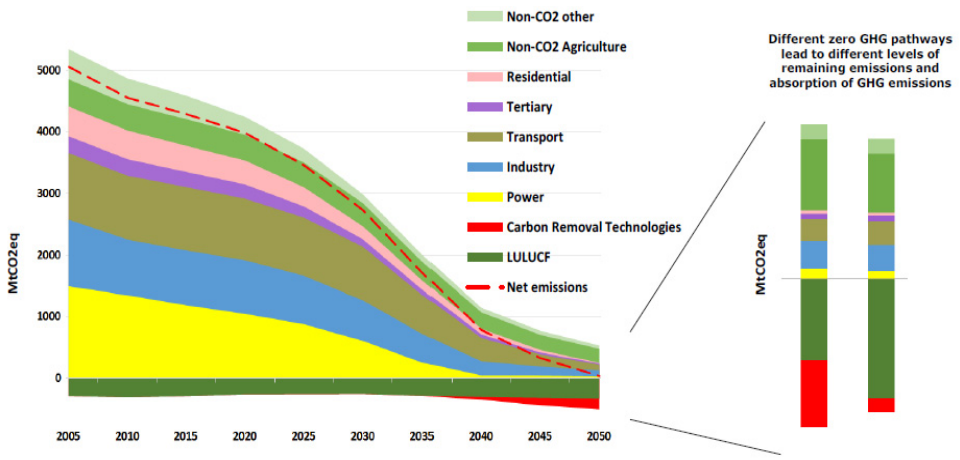

Fig. 1. Greenhouse gases emissions in –1.5°C reduction scenario. *Source:* [Clean Planet, 2018, p. 23]

What does the adoption of the new reduction targets by 2050 mean in the perspective of the EU's legislation? How can these new circumstances affect the negotiations of the Member States on the still-unresolved effort sharing policy to meet the 2030 climate targets commitments of the Community? In order to address the above questions it is necessary to have a closer insight into the EU's previous documents on climate change.

1.1. Winter Package

Winter Package is a working name for the document "Clean Energy for All Europeans" [Winter Package, 2016], initially presented by the European Commission on the 30th of November 2016. The Winter Package embraced a legal framework for two areas agreed on a political level, i.e. the so-called Second Climate Package, approved by the Council on the 23rd of October 2014 [Conclusions, 2014], where the suggested reduction of greenhouse gases by 2030 was defined and the parallel increase of renewable energy consumptionand the improvement of energy efficiency were promoted. The second document was the Energy Union strategy delivered by the Commission and accepted by the Council on the 26th of November 2016 [Conclusions, 2016]. Figure 2 presents the interrelations between strictly political documents and particular EU directives, decisions or regulations, which were negotiated and agreed by the end of 2019.

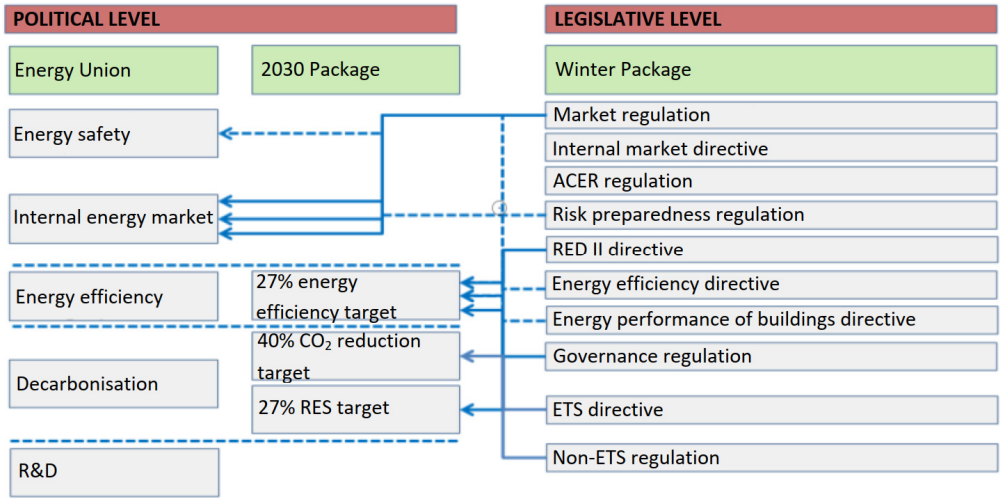

Fig. 2. Scheme of interconnections between political documents and legislative level (authors' own elaboration)

A particular attention should be drawn here to the target levels of increasing the use of renewable energy in the final gross consumption (RES target) and the increase of energy efficiency. In 2016 both targets were assumed at the level of 27% in relation to particular reference thresholds. As a result of lengthy negotiations, the following reduction, RES and efficiency targets were agreed in the middle of 2019:

- reduction of greenhouse gases emission by 40% in relation to the emission for 1990 (which translates into the following levels from the year 2005: –43%in EU ETS sectors and -30% in non-ETS),
- at least 32% share of renewable resources in the final gross energy consumption,
- increase of energy efficiency by 32.5%.

The discussion on climate change was going on not only on a European level, but also worldwide. Already during the Paris COP 21 conference in November 2015, an ambitious

aim was proposed to strengthen the global response to negative processes by keeping a global temperature rise this century well below 2°C (or even 1.5°). As a matter of fact, most research studies clearly indicate that without adopting any serious measures, by the year 2100 a global temperature may rise even by 4.5°C.

Regardless of a political change in the European Parliament as a result of 2019 elections, at the beginning of 2020 the European legislation was anyway prepared for the implementation of new and ambitious 2030 climate targets in the EU's economy. What still remains to be resolved, however, is to negotiate and agree on effort sharing among particular Member States to meet the common climate targets. The proposals of such commitments of particular countries in achieving a common European target were a subject of National Energy and Climate Plans, whose amended versions were submitted to the European Commission by the end of 2019.

1.2. Green Deal

Shortly after taking over the power by the new European Commission, as a result of negotiations among political groups, already in November 2019 the EU returned to the main target of achieving climate-neutral economy by 2050. On the 12th of December 2019 the European Council decided to press ahead with the plan and provided a political guidance on the endorsed policy in the document called the Green Deal [Green Deal, 2019]. Although the conclusions secured an opt-out for one of the Member States (Poland), the rules of the game were commonly accepted and since that very moment the reorientation of the entire European economy into climate neutrality has been under way.

Although the Green Deal is a political document, it still contains wide references to economy and environment. Figure 3 presents the areas of economic and environmental activities embraced by the document, which are to be provided with proper legislative content, multiannual implementation programs and sources of finance.

The Green Deal policy document still fails to provide many precise details of a future implementation program. The document only makes provision for an increase of greenhouse gases reduction by the year 2030 by at least 50%, or even 55% (now it is 40%). As a result, the EU's law is to be revised and necessary amendments are to be introduced by June 2021. A relevant review will have to embrace, among others, directives on renewable energy and energy efficiency, regulations on European cross-border networks and initiatives referring to thermal renovations of buildings. National Energy and Climate Plans submitted to the EC by the end of 2019 were to be evaluated by the middle of 2020.

So, what sort of economic, climate and energy targets should the EU Member States expect in 2020? As a matter of fact, the European legislation is under a permanent review and revision. Although the results of 2008 Climate and Energy Package with its 20-20-20 targets have not been evaluated yet (20% reduction of greenhouse gases, reaching 20% of RES share in gross energy consumption and 20% increase of energy efficiency by the end of 2020), the EU has already set targets for 2030 in its Winter Package and further new ambitious targets in the Green Deal. The European Commission, however, has failed to perform any analysis on the influence of the Green Deal on the entire European economy and the economy of particular Member States (Impact Assessment) according to standard procedures (earlier such analyses were regularly performed with the use of PRIMES model). Hence, a basic analytical tool is missing before starting any financial negotiations with particular Member States. Undoubtedly, the discussions with countries heavily dependent on fossil fuels will be extremely difficult since they will be likely to expect

Fig. 3. Areas of economic activity embraced by the European Green Deal [Green Deal, 2019]

higher compensation from the planned Just Transition Fund. Therefore, a possible scenario in the nearest two years may embrace the following actions: an evaluation of Winter Package programs implementation and legislation necessary in meeting its targets, performing an Impact Assessment of new regulations on the EU's economy and the economy of particular Member States, active revision and evaluation of existing regulations towards achieving the new objectives, defining new reduction and efficiency targets for a climate-neutral economy to be fulfilled by 2030, re-negotiating the commitments of particular Member States in the National Energy and Climate Plans (NECPs) and finally hard budget negotiations leading to a just transformation. In fact, the scenario is likely to be altered as a result of the crisis after the outbreak of COVID-19 virus in early 2020 and rescue measures adopted to recover national economies worldwide.

1.3. The EU's response to the COVID-19 pandemic: A recovery plan for Europe

As a result of a massive spread of COVID-19 pandemic in March 2020 the world economy was frozen for several months, global delivery chains were broken and human activity was seriously restricted. The pandemic also affected the energy sector. In countries with a total shut-down of economy (e.g. Italy), a massive drop of energy consumption by 25% year to year was observed in March and April. In the same period, the use of energy in Poland decreased by nearly 10%, which naturally caused a lower energy production, mostly in large coal-fuelled power plants. As a result, also reduction of coal exploitation and energy consumption was observed in coal mines. In addition, already excessive hard coal reserves became even larger. In this respect, it

is worth noting that at the end of 2019, the coal reserves in mines reached 4.8 mil Mg (tonnes), whereas in power plants they exceeded 9.2 mil Mg, which amounts to the total of 14 mil Mg.

The European Commission resolved to adopt the Green Deal as a core measure for the European economy recovery after the pandemic crisis and despite the initial wave of criticism for acting too slowly, the EC soon took the initiative and proposed large additional financial funds for the three years to come, independently from the next long-term budget for the years 2021-2027 of around 1,100 billion euro. The European Commission communication "Repair and Prepare for the Next Generation" [Next Generation] of the 27th of May 2020 specifies the details of the recovery plan. An additional financial stimulus of 750 billion euro was proposed, which in its major part (500 billion euro) will be allocated as non-returnable grants for particular Member States, whereas the remaining 250 billion euro will have a form of loans. An initial division of funds into the Member States is presented in Fig. 4.

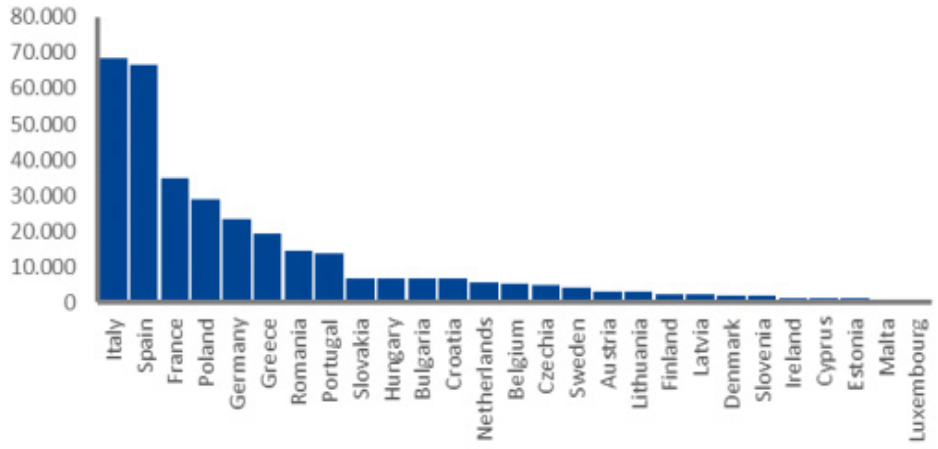

Fig. 4. Initial division of budget from the recovery fund in mil EUR.
Source: [NextGeneration, 27th May 2020]

Notwithstanding the rescue efforts for the economy in its phased reviving process, the European Commission continued to work on the documents and implementation arrangements of the Green Deal in the first half of 2020. In March, the Commission presented a draft regulation establishing a framework for achieving climate neutrality target and amending the Regulation (EU) 2018/1999 (European Climate Law) [Climate Law], which proposes to transfer to the EC the right to determine the route of greenhouse gas emission reductions for the period 2030-2050. At the same time, the Commission launched a public consultation on raising the reduction target for 2030 to at least 50%, instead of the 40% agreed in the Winter Package. In mid-2020, it is not possible to assess the impact of implementing specific Green Deal solutions during the pandemic. The outcomes of these measures will affect every single citizen of the European Union. They will influence his or her way of life, customs and require some kind of personal contribution. In addition, there are a lot of unknowns.We do not yet know many technological solutions that will replace obsolete emission solutions in transport or energy storage. There is no assessment of how remote working will affect energy demand. We do have any reliable data of how the progress

in robotics and digitalisation will accelerate. We still do not know the answer to the question: will the hydrogen economy be so advanced as to replace other emission energy carriers?

Under such conditions, how to responsibly plan a secure electricity system in Poland, combined with a European system that will meet the requirements of a climate-neutral economy in 2050?

2. Condition of electricity system in Poland in early 2020

The electricity system of Poland and its entities, throughout the entire transition process of Polish economy after 1989, for environmental and economic reasons were constantly modernised, while retaining the ability to continuously supply electricity to the economy and municipal customers at prices ensuring regular development. Due to the high dependence of domestic electricity generation on coal (around 75%), the production costs and consequently prices are mainly shaped by the following factors:

- the price of steam coal and its availability on the domestic market
- the price of greenhouse gas emission allowances (EUA),
- costs of generating equipment modernisation in order to meet environmental requirements (IED Directive).

By mid-2018, greenhouse gas emission allowance prices were fairly stable and low at around 5 euro/t CO_2, which at the price of hard coal at around 8-10 PLN/GJ allowed electricity to be offered to the domestic market at around 40 euro/MWh. Lignite producers had a significant cost advantage as they could use 30% cheaper fuel, and higher lignite emissions at a low price of allowances did not result in a loss of competitiveness. Energy prices in neighbouring markets remained slightly lower at the time, but this was due to falling investment costs for renewable technologies and still favourable support schemes offered to plant owners. Polish energy groups and private investors tended to diversify their manufacturing assets towards less-carbon and renewable technologies, which allowed for a certain market balance to be maintained in the growing European market. The situation changed rapidly around mid-2018, when, as a result of the introduction of regulatory mechanisms (Market Stabilisation Reserve) and the liberalisation of EUA turnover by the banking sector, allowance prices reached the level of around 25 EUR per tonne of CO_2. At the same time, the cost of hard coal increased to 10-12 PLN/GJ, which resulted in the cost of producing electricity from hard coal increasing by around 100 PLN/MWh (25 EUR/MWh). In view of the risks of losing the competitiveness of the economy, as well as concerns about social unrest, the Polish government has taken steps to freeze energy prices for individual consumers and parts of industrial consumers in 2019. As a result of these measures, after notification of the state aid rules, a compensation scheme for eligible recipients was introduced. However, this does not change the situation that in future periods the economy has to prepare for higher electricity prices in Poland.

The capacity structure installed in the Polish power generation system in 2019 is illustrated in the following graphs:

In 2019, the generation potential increased by 2 GW of capacity on hard coal and almost 1 GW of capacity installed in photovoltaics, mainly in prosumer installations.

In 2019, 15% of electricity was produced in renewable sources. The graph below shows the structure of RES production in the decade 2010-2019.

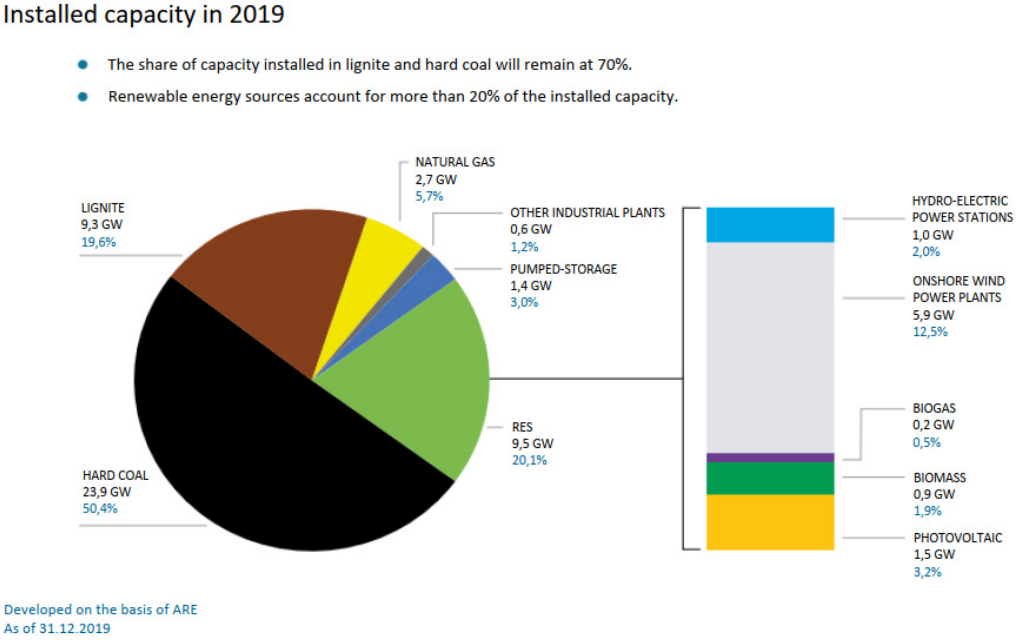

Fig. 5. Capacity structure installed in National Power System (KSE) in 2019. *Source:* Forum Energii

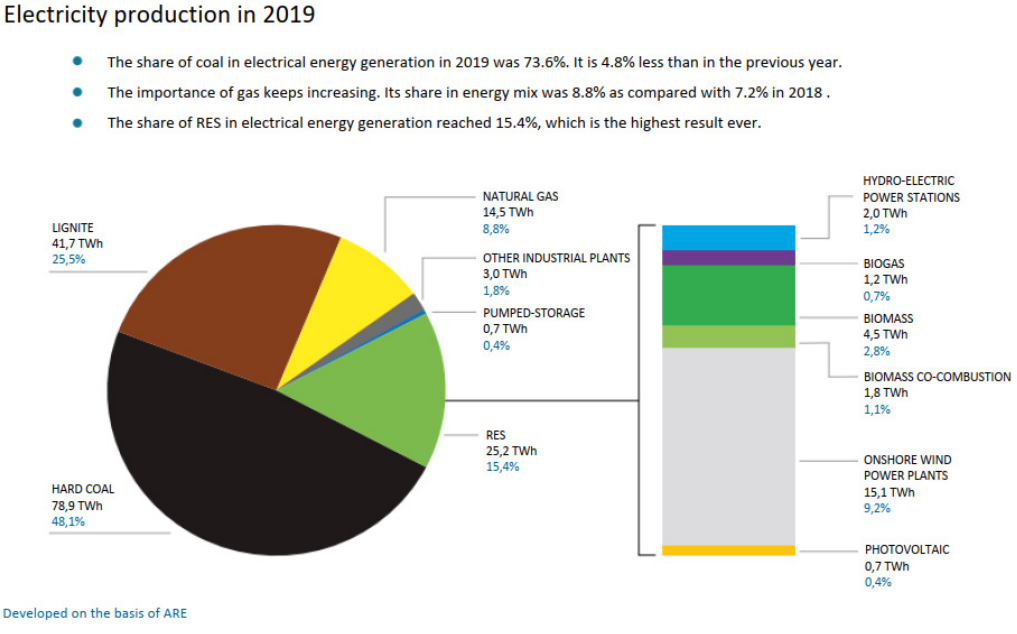

Fig. 6. Electricity production structure in 2019. *Source*: Forum Energii

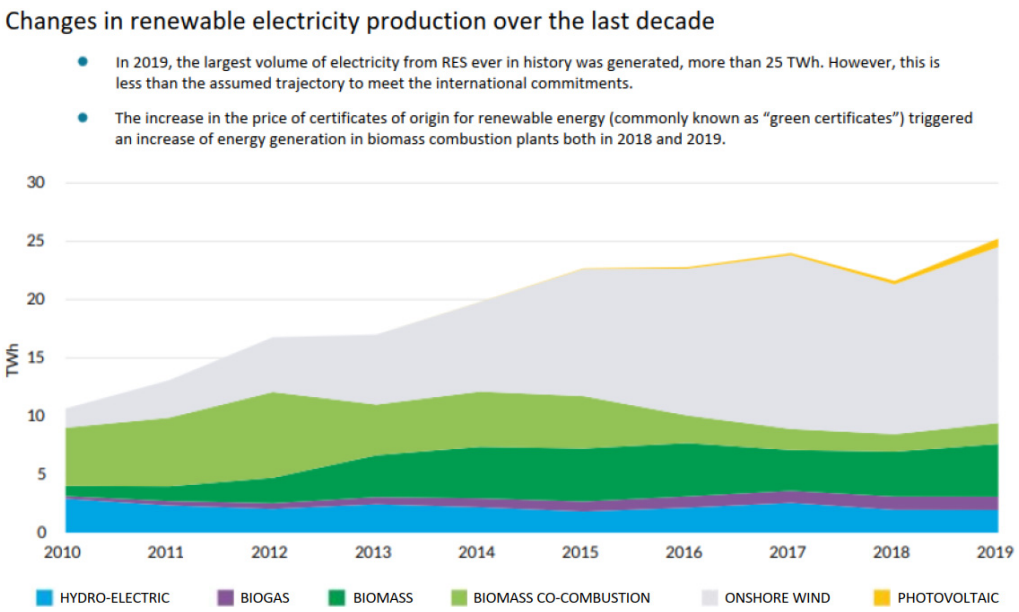

Fig. 7. RES production structure for the period 2020-2019. *Source:* Forum Energii

Since 2015, energy imports in Poland are higher than exports and the trend continues with the value of imports for 2019 reaching as much as 10.6 TWh.

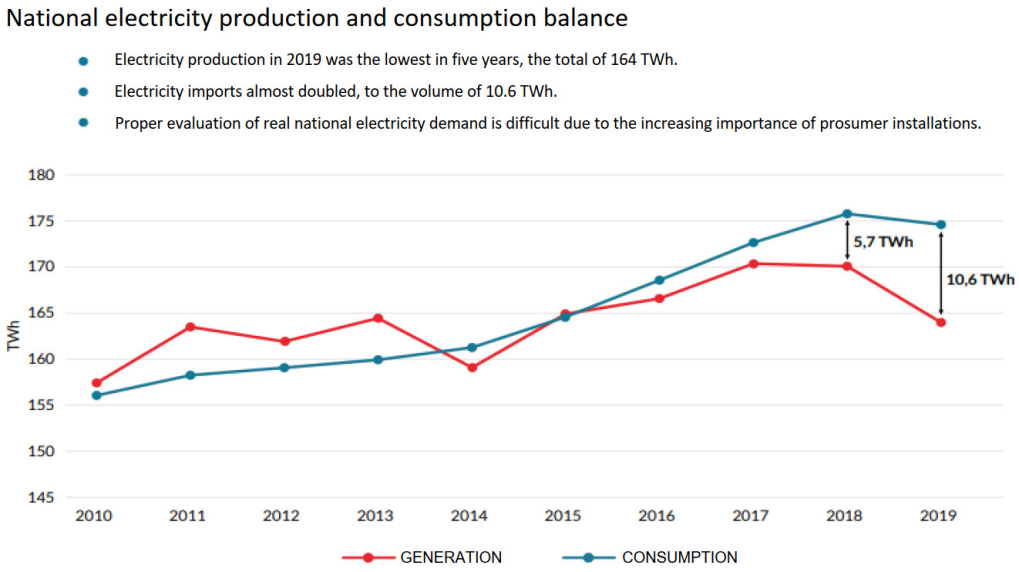

Fig. 8. National electricity consumption and production balance for the period 2010-2019.
Source: Forum Energii

As a result of pandemic-enhanced freezing of the economy, in March and April 2020 a serious decrease in electricity consumption and production was observed in Poland. Temporarily on European markets, the price of energy has fallen to only a dozen euro per MWh, i.e. only half the price for greenhouse gas emission allowances. Despite continued lower energy consumption, prices are returning to levels from the end of 2019. Figure 9 presents the level of electricity prices on the markets connected to the Polish energy system.

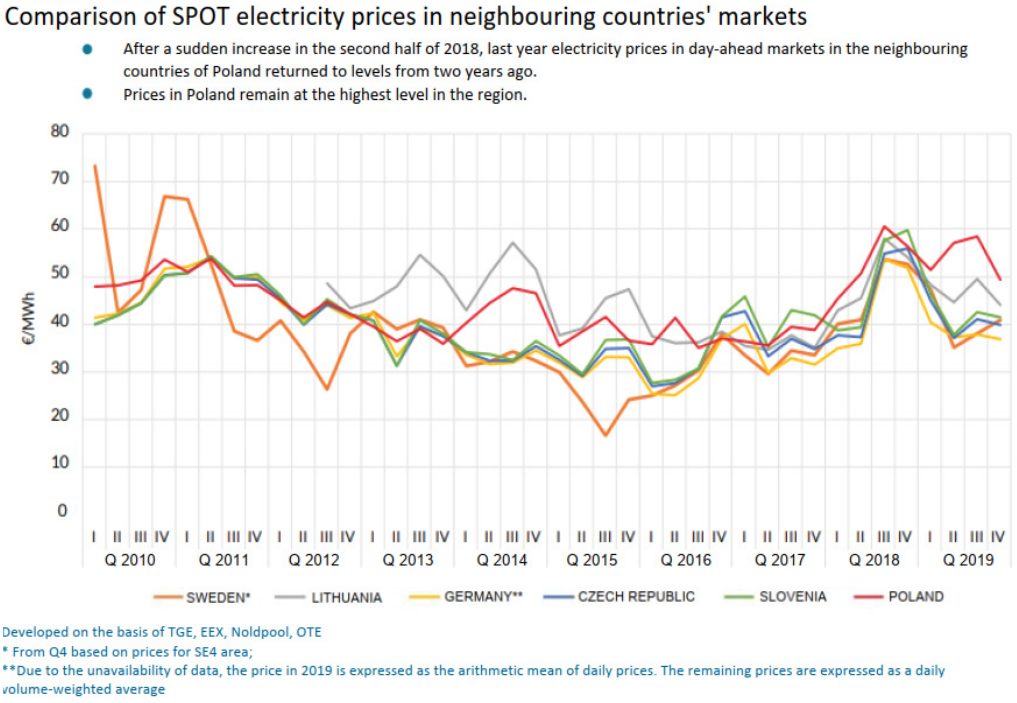

Fig. 9. Spot Market energy prices in connected markets. *Source:* Forum Energii

At the beginning of 2020, the Polish energy industry retains the capacity to continuously supply the national electricity system and to operate efficiently in conjunction with the EU's growing continental market. Rising prices of greenhouse gas emission allowances, the challenges of environment-friendly modernisation, the need to replace obsolete generation and network assets due to their technical wear and changing functions in the system generate the following problems for Polish energy industry to be solved:

- **Upgrades to the environmental requirements of BAT conclusions**

The need to implement a programme to modernise power plants to meet emission requirements stems from the so-called BAT conclusions (IED directive requirement). The expected expenditure for the program implementation by 2021 amounts to around 6-8 billion PLN. A further revision of emission levels for generation sources is expected in 2028 and it will also require a comparable scale of expenditure.

- **Investments in new generation sources**

In 2020, the construction of the last four 1,000 MW units for hard coal and 500 MW unit for lignite is to be completed. However, the plan to build the 1,000 MW Ostrołęka power plant, despite being contracted as part of an auction on the capacity market, has been abandoned. As a result of the auctions conducted so far on the capacity market for the period 2021-2024, apart from two 700 MW projects for the Dolna Odra PP, no other projects have been submitted. Energy producers who have contracted capacity in the auction for the subsequent years will receive a total of about 40-50 billion PLN over the next decade. The way in which these funds are invested is crucial in the process of substituting outdated and replaced coal-fired units with new generation modern blocks. So far, there is no information whatsoever on any new investments, which poses a considerable risk in ensuring a smooth exchange of power of the Polish energy system in the nearest years. An analysis of the needs in this area will be discussed in the next chapter.

- **Ensuring regulation reserve in the electricity system**

The rapid development of renewable sources, supplied on a discontinuous manner, makes coal blocks work less frequently and, on the other hand,requires more regulation reserve capacity of them. This process has been so far and still remains the main reason for the introduction of the capacity market. The capacity remuneration, in addition to payments for electicity, is intended to cover the maintenance costs of the availability of the blocks, which will be a reserve for energy supplied on a discontinuous basis from RES. According to the decision notifying the capacity mechanism, from mid-2025 on only those units whose emissivity is less than 550 kg CO_2/MWh can participate in the capacity market and hence charge for such a service. This in turn means another challenge of how to maintain availability on the one hand and avoid the closure of about 20 GW of coal-fuelled power for economic reasons on the other.

- **Opening up connected regional markets to energy trade**

In accordance with the rules introduced by the so-called network codes, from 2021 foreign operators of generation units in the combined markets will be able to offer electricity on intraday, day-ahead and balancing markets, while having access to cross-border transmission capacity. The transmission capacities on cross-border connections are to be made available up to 70% of their technical capacity, which means increased competition in the domestic energy market.

- **Uncertainty of regulations and financial markets**

Investment and development trends of energy companies on the Polish market are very uncertain. In December 2019, the government presented a revised and updated draft of Energy Policy of Poland until 2040, but in fact it was not formally adopted, which results in fairly conservative investment strategies, mostly based on national energy resources. At the end of 2019, the European Investment Bank announced a halt to funding for all fossil fuel projects, including gas. This creates a risk of a serious gap in manufacturing assets after 2030. Another uncertainty stems from the adoption of the principle that the ways of spending money from the European Economic Recovery Fund are to be decided by the Commission, which will assess whether the national programmes are in line with NECPs and give final approval for the implementation of the investment. Although this uncertainty can be seen as an opportunity to invest in green electricity production and decarbonise technological processes in energy-intensive sectors.

3. Draft of Polish Energy Policy until 2040: Risks and correction proposals.

Poland's current Energy Policy is a document dated 2009, when the so-called "three 20 targets" climate and energy package entered into force in the EU. Since then, no new documents have been adopted in Poland, despite some attempts. Meanwhile, changes in EU climate policy at the time were very dynamic (i.e. the Winter Package adopted in November 2016, the Green Deal of December 2019). The absence of a new document creates a considerable level of confusion about the Polish government's preferred ways of transforming the economy, including the energy sector. In early 2020, the Ministry of State Assets presented another version of the project of the Polish Energy Policy [PEP 2040, No.2.1] in line with the National Energy and Climate Plan (NECP), which contains Polish proposals for a contribution to the European climate policy and was presented to the European Commission at the end of 2019.

In the document submitted to the European Commission, Poland declared its participation in meeting the European targets for 2030. These objectives, as well as other strategic activities contained in the EPP 2040 project, are set out in Figure 10.

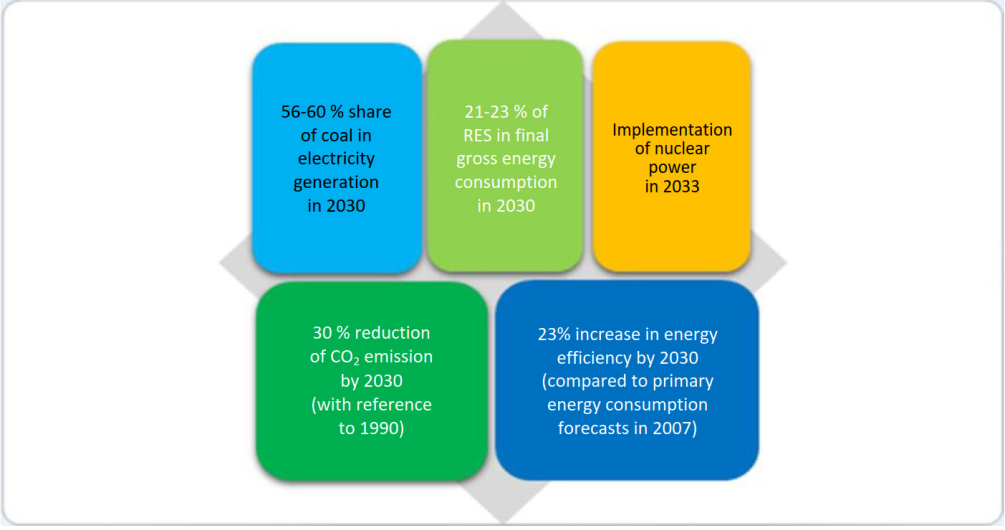

Fig. 10. Targets of EPP 2040 project. *Source:* PEP 2040

Interestingly, the targets presented in Figure 10 for reducing greenhouse gas emissions, as well as increasing the share of renewable energy in gross consumption and increasing energy efficiency, are significantly lower than those adopted at the European level. The Polish economy, and in particular its coal-dependent electricity generation sector, face an extremely difficult task of achieving climate neutrality in the 2050 perspective. It seems likely that achieving this objective will require a longer period of time and an increased level of funding under the European principle of solidarity-based just transition. Nonetheless, Poland's participation in the Green Deal programme and the EU's common energy and climate policy is beyond any discussion.

Meanwhile, the Ministry of Climate has already announced a revision of the not-yet-adopted (sic!) EPP 2040 project and a new proposal by the end of 2020, which will see a stronger shift towards renewable energy and climate neutrality.

The project of EPP 2040 addresses such major challenges as:

- **Ensuring an adequate level of energy security for Poland**
- **The need to maintain existing generation capacity for the transition period – system reserve longer than by 2030**

In 2019, out of nearly 46 GW of total capacity installed in the national system, nearly 36 GW were provided by coal-fuelled power plants, mostly obsolete. A significant part of those plants is to be closed down in the period 2025-2035 (about 16.5 GW), mainly due to their age and low efficiency. Some of the old units cannot be liquidated as they must remain as a strategic reserve, which will be involved only periodically and producing less and less energy, but ensuring the physical security of the electricity system (power supply). It is necessary to invest in the modernisation of these units in order to meet the environmental requirements of the BAT conclusions, as well as to achieve more work flexibility in the national system (increased number of shutdowns and starts, lower minimum power, faster power growth in time).

Given that in 2035 the demand for capacity is estimated at 63 GW (Fig. 11) and approximately 16.5 GW of the current capacity is permanently eliminated by this time, we must be aware that around 33.5 GW of brand new capacity, obtained mostly from low-emission and renewable technologies, will have to be restored. A detailed account on the matter is given in Chapter 5.

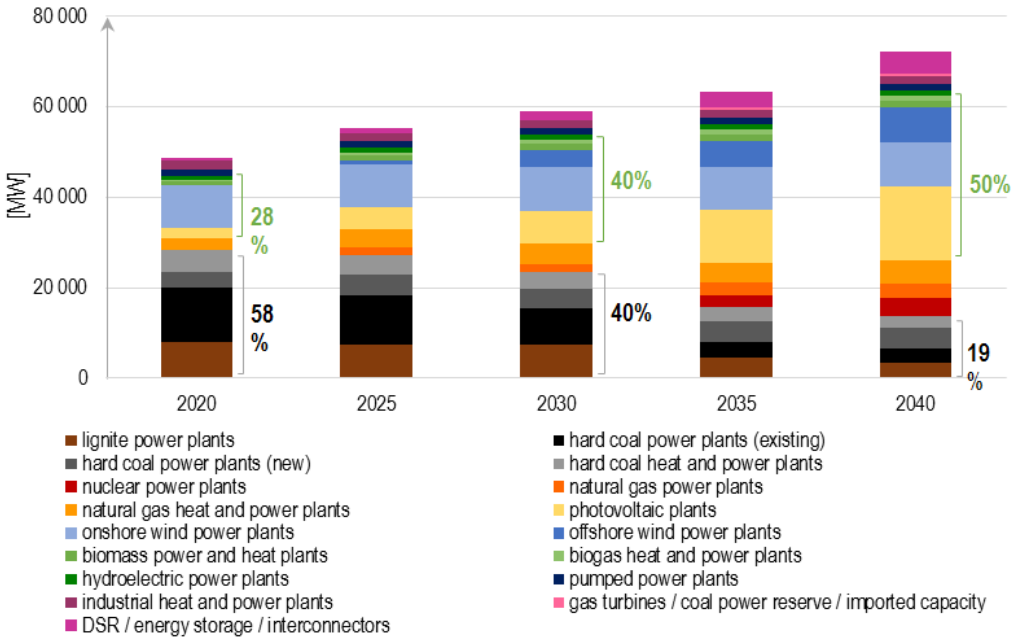

Fig. 11. Forecast of changes in the fuel structure of generation capacity, source: PEP 2040

- **Risk of not launching a nuclear power plant by 2033**

Among the strategic objectives of EPP 2040, the implementation of nuclear energy in 2033 plays a key role in the decarbonisation process of national energy generation. This objective should also be considered in the context of the state's energy security, i.e. the possibility of providing a sufficient volume of energy to the National Electricity System, taking into account possible reductions in demand, the availability of electricity on cross-border connections, as well as the variability of energy generation from renewable sources. Current nuclear projects held in Europe, but also worldwide, are characterised by a certain level of unpredictability in their schedule and budget. Therefore, the following questions arise: What is the alternative scenario in the context of the state's energy security in the event of a possible delay in the implementation of the nuclear programme in Poland or the abandonment of nuclear power at all? What are the possible ways of capacity and electricity supply to the National Electricity System, including the potential mix of energy sources? What about the level of the state's energy security?

4. Current condition and prospects of hard coal and lignite mining in Poland

Despite the huge criticism, coal is now, and as all signs point, will remain an important source of electricity and heat supply in the world for the next 30 years. As a matter of fact, the world still produces the most electrical energy from coal. For instance, in 2019, around 40% of electricity on average was produced from coal worldwide, nearly 25% in Europe and around 80% in Poland.

In order to find out what the condition of Polish coal is, the situation is discussed separately for hard coal and lignite.

4.1. Hard coal mining

According to Polish Geological Institute, ***the total geological resources of hard coal in Poland are estimated at the level of 60,5 billion Mg (tonnes)*** (as of January 1st, 2018). The prognostic geological resources are divided into: ***balance sheet resources of approximately 46.23 billion Mg*** and ***off-balance sheet resources of nearly 14.17 billion Mg***. In turn, the balance sheet resources of hard coal are divided into: ***balance sheet resources of developed deposits of almost 22.3 billion Mg*** and ***balance sheet resources of undeveloped deposits of 24.93 billion Mg.*** Based on the balance sheet resources of undeveloped deposits, it is possible to construct new mines in Poland, but this seems to be a rather unpopular and unlikely decision. In the light of a clearly declared decarbonisation in the EU, it is difficult to expect any approval for the construction of new coal mines. As a matter of fact, in the balance sheet resources, ***the industrial resources amount to only 3.6 billion Mg***, including ***developed industrial resources of nearly 2.9 billion Mg***. The value of industrial resources at the current rate of extraction is sufficient on average for approximately 40 years of operation [Dubiński et al. 2020]. However, we should bear in mind that these resources are not evenly distributed among the operating mines. In fact, among the mines producing energy coal, there are only 5 mines with large resources that allow them to operate for more than 40 years at their current level of extraction. By contrast, the majority (14 mines) will end up their operations due to a lack of resources in less than 25 years, and 7 of them even in less than 10-15 years. This uneven distribution of resources in individual

mines combined with specific mining conditions of each of them (resulting from the capacity of shafts) will indisputably result in a decrease in the extraction of hard coal from Polish mines in subsequent years. In fact, such a trend can be observed already today.

Assuming the perspective level of coking coal mining in 2040 at 12.5 mil Mg, then the extraction of hard coal for energetic purposes in 2040 in Poland will not exceed 34 mil Mg. The value of coal mining may be reduced, as by 2040 the average depth of operation will increase by about 150 m (from 780 m currently to more than 930m). With the increase in depth, there will be a concurrent increase in the hazard of methane, fire, rockburst, water, dust, radiation, climate, sudden outburst of gas and rock. Furthermore, these hazards will occur in combination (e.g. methane and fire hazard) which will make operation extremely difficult and will significantly worsen the economic performance of mines (Dudek et al 2020). For example, the "Budryk" mine is already operating at a depth of 1,290 m, where the temperature of the walls exceeds 50 degrees and the combined hazards have increased significantly.

In 2018, a total of 63.4 Mg (tonnes) of coal was mined, including: 50.9 mil Mg of coal for energetic purposes and 12.5 mil Mg of coking coal. On the one hand, only less than 3 mil Mg was exported and more than 62 mil Mg was consumed in Poland. On the other hand, there was a record-breaking import of coal from abroad, which amounted to 19.7 mil Mg (80% from Russia), among others to cover shortages in 2018. Looking at the volume of imports in each year, there is clearly a chaos, lack of import policy, or any correlation with the possibilities of Polish mines and the changing demand for coal.

This chaotic tendency is illustrated by the changing volume of coal imports to Poland in recent years:

2012 – 10.5 mil Mg (tonnes),
2013 – 10.3 mil Mg,
2014 – 10.0 mil Mg,
2015 – 8.2 mil Mg,
2016 – 8.5 mil Mg,
2017 – 12.0 mil Mg,
2018 – 19.6 mil Mg (sic!)
2019 – 16.5 mil Mg.

Massive coal reserves (currently close to 14 mil Mg of coal for energetic purposes) have been placed on heaps at Polish mines, despite a clear drop in production down to 61.8 mil Mg in 2019. Large coal reserves are due, on the one hand, to the huge imports of mainly Russian coal and, on the other hand, to lower demand for coal resulting from exceptionally warm winters, which has significantly reduced demand for coal in heating and energy, as well as the coronavirus pandemic.

Figure 12 shows a comparison of coal production and consumption, as well as the export-import balance.

Projections of coal production by 2040 are presented in Table 1 and compared with the possibilities of mines without significant investment schemes (construction of new mines, new levels, etc.). It seems that with certain investments, the demand for coal in Polish power plants and combined heat and power plants should be covered by mining in domestic mines. The problem is that the EPP 2040 forecast fails to take into account the total of coal consumption in Poland (also in households, small combined heat and power plants, small industrial plants, etc.), which in 2019 amounted to about 10 mil Mg (cf. Fig. 12). Since 2019, the demand for hard coal has slowly started to decline, which is the result of the process

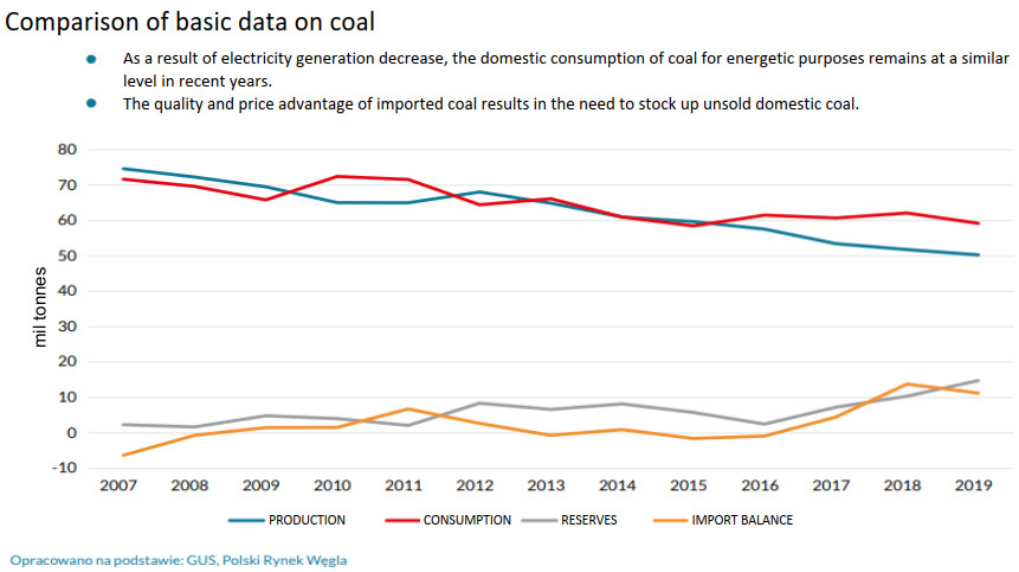

Fig. 12. Coal production and consumption in the period 2010-2019. *Source:* Forum Energii

of modernizing production processes, the use of RES in small farms, providing buildings with thermal insulation, etc. The forecast of total energy coal consumption in Poland is shown in Table 1. The table also compares the forecast of total energy coal consumption in Poland with the exploitation potential of Polish mines (without investments). These projections indicate that 9-13 mil Mg of coal imports from abroad will still be absolutely necessary.

TABLE 1

YEARS	2020	2025	2030	2035	2040
Projection of hard coal for energetic purposes production (in mil Mg) according to EPP 2040	55	51	42	35	30
Projection of hard coal for energetic purposes gross consumption (in mil Mg) according to EPP 2040	53.5	45	36.5	30	25
Potential mining of hard coal for energetic purposes without any investments (inmil Mg)	51	50	40	32	30
Forecast of the total consumption of coal for energetic purposes (in mil Mg) according to theauthors'' opinion	60	55	50	45	40
Shortage of hard coal in Poland, which has to be supplemented by imports (in mil Mg)	9	5	10	13	10

4.2. Lignite mining

The world's lignite production in 2018 was just under 800 mil Mg. In the European Union, over the past decade, lignite mining was at a level of around 400 mil Mg per year. Germany, which in only recent years extracted more than 180 mil Mg of lignite annually, is the leader

in the world and in Europe. Since 2015, there has been however a gradual decrease in lignite production in Germany and the parallel decrease in electricity production from this sort of fuel (Table 2; according to Informationen und Meinungen 01/20, DEBRIV, Bundesverband Braunkohle). Despite the decline in lignite demand, Germany is building new lignite mines to restore production capacity and maintain energy security.

TABLE 2

Years	2015	2016	2017	2018	2019
Lignite production (in mil Mg)	178,1	171,6	171,3	166,3	131,3
Electricity generation (inTWh)	154,5	149,5	148,4	145,6	114
Decline in electricity generation (in %)	100%	97%	96%	94%	74%

Poland with over 50 million Mg is ranked 7th in the world and second in the EU. In recent years, the EU countries and the world have seen a slight decline in lignite production.

Currently deposits in operation in Poland (i.e. Bełchatów, Konin, Turów, Sieniawa) provide a stable level of extraction at an average level of about 50 mil tonnes per year until 2030. Unfortunately, between 2030 and 2040, due to the depletion of lignite reserves, there will be a sharp decrease in the extraction and production of electricity from this fuel. Lignite mining is expected to be at a level of around 25 mil Mg in 2035 and only around 12 mil tonnes in 2040.

As a matter of fact, these figures are lower than expected in the 2030-2040 lignite demand, as 35mil Mg was planned to be extracted in 2035 and 22mil Mg in 2040.

In view of the fact that:

- the average annual growth rate of electricity consumption in the period up to 2040 is projected at 1.5% (an increase of almost 40% in 2040),
- lignite mining will be less than its consumption,
- there is a huge risk of not starting nuclear power plants by 2035,
- overly optimistic assumptions about renewable energy have been adopted,

possible and feasible alternatives should be considered immediately. One of such alternatives may include the start of new lignite mine construction now.

5. Analysis of capacity generation availability and production structure after 2035

Figure 13 shows a graph of the projected permanent withdrawal (decommisining) of generation units in the National Electricity System in the years 2016-2040.

It is noteworthy that in the period 2030-2035, almost 10 GW of capacity is projected to be withdrawn completely, while simultaneously during this time frame the first nuclear power plant is to be launched. In the power balance presented in EPP 2040 strategy (PEP 2040 table 17, p. 20), nuclear capacity of 2.6 GW is projected by 2035 and 3.9 GW by 2040.

The estimated power demand in 2035 is about 63 GW. Meanwhile, the capacity installed in the system in early 2020 was just over 46 GW. In the period 2021-2035, a permanent discontinuation of approximately 16.5 GW of power is assumed. This means restoring nearly 33.5 GW of new capacity in low-emission and renewable technologies, energy storages and demand reduction systems. What are the consequences of the new capacity projection for 2035?

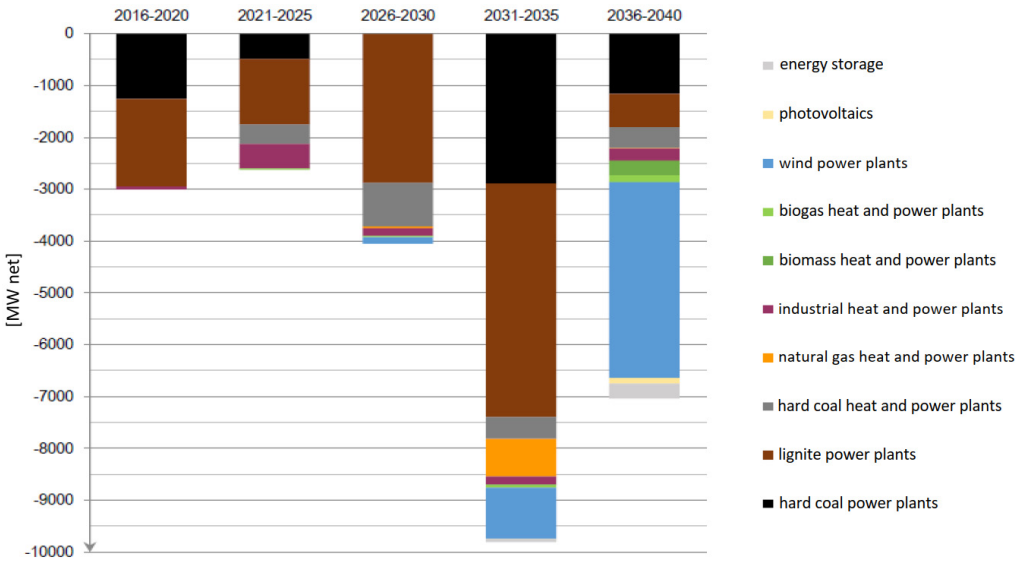

Fig. 13. Forecast of permanent withdrawal of generation units in 2016. *Source:* PEP 2040

The envisaged investments include:

– Hard coal (Jaworzno)	– **900 MW**
– Lignite (Turów)	– **450 MW**
– Combined heat and power plants / gas-fuelled power plants	– **4,400 MW**
– Nuclear power plant	– **2,600 MW**
– Offshore wind energy installations	– **5,600 MW**
– Photovoltaic plants	– **10.000MW**
– Biomass / biogas plants	– **1,400 MW**
– Energy storage/DSR	– **3,100 MW**
Total:	– **28,450 MW**, i.e. **28.45 GW**

Thus, after critical analysis and verification of projections, about 5 GW of power is missing (up to the amount of 33.5 GW of declared restoration). In the event that the nuclear power plant cannot be launched, the missing capacity will increase to as much as 7.6 GW.

Is there therefore any risk concerning the reconstruction of generation units in line with the schedule, budget and technologies foreseen for the EPP 2040 strategy?

In fact, nowadays the energy market is regarded as uncertain, hence a relatively high level of cautiousness and tendency of risk avoidance is observed in the financial markets investing in power generation sector. The expected investment in the EPP 2040 programme in the period 2021-2035 amounts to approximately 48 billion euro, i.e. more than 200 billion PLN (*cf.* Fig. 14). Seemingly, with rather limited investment potential of some Polish energy groups, there is a high financial risk of such a gigantic investment programme.

Numerous instances show that current nuclear projects in Europe and around the world are unpredictable in their schedules and budgets (investment exceeds up to three times the originally planned expenditure). For example, nuclear block 3 in Olkiluoto, Finland, launched back

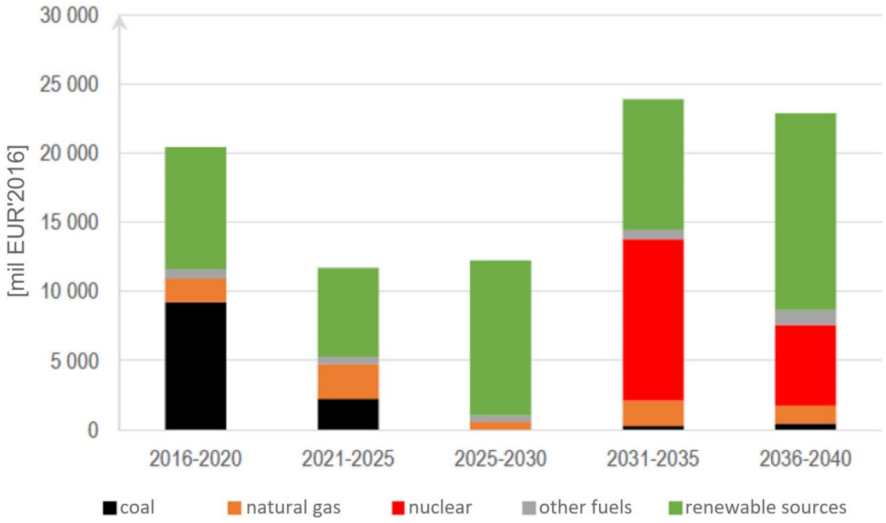

Fig. 14. Expected investments in the Polish power generation sector in 2016-2040. *Source:* PEP 2040

in 2005, will probably be put into operation only in 2020 (i.e. after 15 years) at a cost of around 36.5 billion PLN. The same is true of the French Flamanville project.In January 2020, the French Government issued a communication on postponing the decision to constructany new nuclear power plants in France to 2022.

The fundamental issues for Poland's new energy policy, in the context of the submitted draft, are as follows:

1. Redefining the concept of energy security of the State in such a way that with reference to the capacity supply to the national system, the potential should be based on national resources and, with reference to energy trade, the market should be fully open to cross-border trade,
2. Analysis of the availability of national generation capacity and coal resources to ensure security of supply during the transition period,
3. Alternative scenarios in the event of a delay in the investment programme in new generation capacities, including in particular the construction of the first nuclear power plant.

Referring to energy security of the National Power System of Poland (KSE) in the period 2030-2040, the authors of the paper argue that the closure of obsolete coal-fuelled power plants and the huge risk of serious delays in the deadline for launching the first Polish nuclear power plant may already in 2035 result in a serious deficit of capacity of about 7.6GW.

6. Energy safety. Power and energy: A brand new safety doctrine.

Yergin (1988) argues that "*the objective of energy security is to ensure an adequate and reliable level of energy supply at reasonable prices in a way that it does not jeopardise the fun-*

damental values and objectives of the state". According to Mazurkiewicz (2008), the level of energy security of a given country depends on the following factors:

- volume and diversification of the national fuel base,
- rate of diversification and use of domestic and foreign sources of energy supplies,
- technical condition of the supply system and forms of its infrastructure ownership,
- fuel storage opportunities, development of national and international connections of energy systems, internal and international economic policies.

The EPP 2040 strategy (PEP 2040, p. 19) states: "*With regard to the role of coal in the electricity balance, it should be pointed out that national coal resources will remain the main element of Poland's energy security and the basis of the state's energy balance*."[1]

The authors of this paper disagree with this view, since domestic coal resources and relevant generation capacity can guarantee the country's energy security only for the nearest 15 years, in terms of providing electricity supplies to the national system in a situation of limited access to energy on cross-border connections and lack of energy generation by unstable renewable sources, as well as a possible reduction in energy consumption (security of capacity supply).

The above conclusion is the result of an in-depth analysis of the total volume of domestic coal resources, its extraction potential and production capacity, which in fact are gradually decreasing (and in the case of lignite, mining and production will start to decline drastically after 2030). The falling share of coal and coal-based capacity, combined with the uncertainty about the start and completion of the nuclear power plant construction, will inevitably result in a serious decline of the country's energy security. Hence, two fundamental questions arise:

1) What is the lowest possible level of energy security, below which Poland's core values and objectives will be seriously threatened?
2) What actions can be undertaken to improve the country's energy security?

Undoubtedly, an important factor in ensuring the competitiveness of national economy and providing inexpensive energy for municipal consumers is the need to open up the domestic market to the European market, including the large-scale and prosumer renewable energy sources. This will reduce the rate of emissivity and provide access to cheaper energy, while maintaining the security of the national electricity system. In a way, coal will then be able to be "dismissed" from the hitherto fulfilled "function" of being "the fundament of the energy balance of the country".However, a borderline level of energy security should be defined, based on available domestic energy resources (including storage facilities) and potential generation resources that will ensure the stability of the national electricity system in the event of a global crisis caused by political events, a pandemic, or any other paralysis of human activity and the interruption of cross-border supply chains.

7. An alternative scenario for providing essential power supply to the national system in the event of a delay in the timetable for the implementation of the nuclear project programme

After carrying out an analysis of energy resources available in the country, and assuming a potential risk of postponing the implementation of the nuclear project by about 5-10 years, or – what also seems possible – abandoning the project of nuclear power plant construction in

[1] Author's own translation

Poland, an alternative scenario should be considered of how to supply sufficient capacity to the national electricity system during the transition period of 2030-2040.

If we assume that for the electricity system it is necessary to provide a controllable capacity of at least 3 GW from the year 2031, and it is crucial to increase the production capacity from a few to a dozen TWh/year (3-15 TWh generation per year), the following several scenarios may be considered, taking into account the generation infrastructure, as well as the grid connections of the national electricity system:

I. On top of all investments focused on meeting the EPP 2040 targets, constructing additional gas blocks with a capacity of about 3GW in the locations of currently existing coal-fuelled power plants. The cost of this variant, with an operation period of about 20 years (in 700 MW units), will amount to approximately 8 billion PLN,
II. Launching a new open-cast to support the modernized Belchatów complex (strategic reserve of 3 GW) as a power supplier in the period 2030-2040. In this option, with a period of operation 2031-2040, investment should be estimated at approximately 2 billion PLN (expenditure comparable to the implementation cost of BAT 2021 conclusions),
III. Launching a new open-cast and construction of a coal gasification plant with CCSU technology for electricity generation with a capacity of about 3 GW. In this option, the investment in the period 2031-2050 will amount to around 24 billion PLN (i.e. 2 mil euro/MW). In addition, investments should be made also on carbon dioxide storage infrastructure, which will generate an additional cost of around 50 euro/Mg (which will affect the price of electricity),
IV. Intervention purchase of 3 GW capacity for the national power system inthe period 2030-2040 to ensure the stability of the system operation. Electricity will originate from dispersed domestic sources, as well as from the European market.

After assessing the advantages and disadvantages of the different options, the following conclusions can be drawn:

1. In view of climate policy, the speed of implementation of the investment programme, as well as the development of gas infrastructure in the country and on cross-border connections, the gas option seems most attractive. However, its implementation would have to mean an additional consumption of around 3 billion m^3 of gas for energy purposes. Therefore, in 2040, the total capacity installed on the gas should reach as much as 11.5 GW, with the expected consumption at the level of about 10-12 billion m^3 of gas, which seems risky due to the need for increased imports from abroad.
2. The option with a new lignite open-cast and the use of CCSU should be considered as rather unrealistic due to the EU climate policy, potential investment volumes, serious limitations of carbon capture and storage technologies and risk of funding.
3. The variant of using a new lignite open-cast during the transition period seems reasonably attractive and its implementation is technologically viable. In this option, with no expenditure to modernize the generation infrastructure, 1 MW of capacity would cost about 67,000 PLN/year. Auction prices in 2019 reached 256,000 PLN/MW/year, so the price is acceptable. However, the problem is that environmentalists believe that lignite-fuelled electricity could only play the role of a supplement in case of possible energy shortages, but should not be generated in a continuous way.
4. The option of contracting capacity with foreign suppliers would have to be guaranteed by inter-governmental agreements. While the risk of supplying sufficient electricity to

the national system does not appear to be very high in this case, however ensuring the stability of the national electricity system with import agreements in extreme situations does not seem to be a particularly good practice.

In conclusion, each of the options presented above has its advantages and disadvantages, but in order to ensure the energy security of the Polish national electricity system (KSE) in the period 2030-2040, one of them should be chosen anyway. Meanwhile, observing a rather unhurried pace of constructing the first Polish nuclear power plant (bearing in mind the still possible abandonment of the nuclear project) and an expected decrease in electricity generation from coal,it is about time to choose one of the presented options and commence its consistent implementation.

8. Conclusions

1. The 2050 target of achieving climate neutrality of the European economy, endorsed by the European Councilin the conclusions of the 12thDecember 2019, and the resolution of the EU Parliament on the Green Deal in January 2020, open up a period of review and redefinition of European objectives and legislation by 2030 and beyond.
2. In particular, the targets presented to the European Commission in the National Energy and Climate Plans (NECPs) at the end of 2019 must be reviewed and redefined.
3. ThePolish NECP submitted to the EU, based on the PEP 2040 project (Polish Energy Policy until 2040), differs significantly in minus in its declarations from the European targets.
4. By 2035, the demand for coal in the Polish power plants and combined heat and power plants may be covered by mining in existing Polish mines. However, this rate of mining will fail to cover all coal consumption in Poland (in households, small combined heat and power plants, small industrial plants, etc.). Hence, imports of coal for energetic purposes will still be necessary.
5. The lignite deposits currently in operation in Poland provide a stable level of production at an average level of around 50 million tonnes per year by the end of 2030. After 2030, due to the depletion of deposits, there will be a sharp decrease in extraction and a serious reduction in electricity generation from this fuel. Lignite mining is expected to fall to nearly 25 million Mg in 2035 and only around 12 million tonnes in 2040. These values are significantly smaller than the ones adopted in EPP 2040 strategy.
6. In the forecasts of power generation capacity demand for the period the 2031-2040, the supplies of necessary capacities are seriously jeopardised. The potential risk is related to the likely delay of the nuclear project and the lack of lignite extraction meeting the levels assumed in EPP 2040.
7. In an attempt at defining the country's energy security, it is proposed to make a distinction between the security of capacity supplies, which should be based on domestic fuel and generation resources, and the security of energy supplies, which should rely on both the domestic and the open European energy markets in order to ensure the competitiveness of the economy and low prices for municipal consumers.
8. The Polish energy sector, in view of the EC's adoption of the Green Deal as a key direction for boosting EU's economic activity, can become an important beneficiary of European funds to revive the economy after the COVID 19 pandemic. In particular, the development of hydrogen technologies in energy and transport is to be expected.

References

Clean Planet, 2018. A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.

Conclusions 2014. Konkluzje Rady Europejskiej z 23,10.2014 r. w sprawie przyjęcia celów klimatycznych na 2030 r., www.Cosilium.europa.com, accessed 10.02.2020.

Conclusions 2016. Konkluzje Rady Europejskiej z 26 11.2016 r. w sprawie unii energetycznej, www.Cosilium.europa.com, accessed 10.02.2020.

Conclusions, 2019. Konkluzje Rady Europejskiej z 12.12.2019 r. w sprawie neutralności klimatycznej, www.Cosilium.europa.com, accessed 10.02.2020.

Forum Energii: Polska transformacja energetyczna 2019 r.

Green Deal 2019. Zielony Ład dla Europy, komunikat i mapa drogowa KE z 12.12.2019 r., www.ec.europa.eu, accessed: 10.02.2020.

Dubiński J., Prusek S., Turek M., Wachowicz J., 2020. *Hard coal production competitiveness in Poland*. Journal of Mining Science **56** (2), 322-330.

Dudek M., Tajduś K., Misa R., Sroka A., 2020. *Predicting of land surface uplift caused by the flooding of underground coal mines – A case study*. International Journal of Rock Mechanics and Mining Sciences. Volume 132, August 2020, DOI: 10.1016/j.ijrmms.2020.104377.

KPEiK, 2019. Krajowy Plan na rzecz Energii i Klimatu, wersja skorygowana, grudzień 2019 r., www.map.gov.pl, accessed 10.02.2020.

Mazurkiewicz J., 2008. *Bezpieczeństwo energetyczne Polski*. Polityka Energetyczna **11**, 11, 313-314.

Next Generation 2020. KomunikatKE „Repair and Prepare for the Next Generation" z 27 maja 2020 r, COM(2020) 456 final.

Winter Package 2016. Czysta energia dla wszystkich Europejczyków (Clean Energy for AllEuropeans), www.ec.europa.eu, accessed 10.02.2020.

PEP 2040, 2019. Projekt Polityki Energetycznej Polski do 2040 r., wersja 2.1 z 18 listopada 2019 r., www.map.gov.pl, accessed 10.02.2020.

Prawo o klimacie 2020. Projekt rozporządzenia ustanawiającego ramy na potrzeby osiągnięcia neutralności klimatycznej i zmieniające rozporządzenie (UE) 2018/1999 (Europejskie prawo o klimacie), 4.03.2020, COM (2020) 80 final 2020/0036 (CD).

Tajduś A., Kaczorowski J., Kasztelewicz Zb., Czaja P., Cała M., Bryja Zb., Żuk St., 2014. *Węgiel brunatny – oferta dla polskiej energetyki. Możliwości rozwoju działalności górnictwa węgla brunatnego w Polsce do 2050 r*. Monografia, Wyd. AGH Kraków 2014 r.

Tokarski S., 2017. *Uwarunkowania transformacji energetyki w kierunku mniej emisyjnej*. W: Zeszyty naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energii PAN w Krakowie, nr 99.

Yergin D., 1988. *Energy Security in the 1990s*. Foreign Affairs 1988, No 1.