Energy security – the case of Polish National Power System facing energy transition's challenges

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Abstract: Energy security plays a key role in energy and economic policy. The importance of energy security has been highlighted by the energy and geopolitical crisis. The aim of this article is to present the crucial threats and challenges facing Polish National Power System, as well as to provide solutions to ensure Poland's energy security over the next 10 years. Article verify the hypothesis that security of electricity supply in Poland may be endangered in the coming years due to, among others, investment gap, coal power plants phase-out and undiversified energy mix. Therefore, it is a necessity to accelerate the investment processes in new generation capacity, especially in nuclear energy. Energy transition plans and energy policy need to be revised in light of the current energy and geopolitical crisis. Rapid growth of photovoltaics improves the energy security, mainly in the summer period, nevertheless, there is still insufficient development of investment in renewable energy sources, particularly in wind energy. In the Polish National Power System there are a lot of constraints such as investment gap, low capacity of transmission and distribution grids and high exposure to climate risk, thus it is necessary to take comprehensive investments to improve energy security in both the short and long term.
Key words: Energy security, energy transition, energy crisis, decarbonisation, coal phase-out, energy policy

1. Introduction

One of the most important objectives of energy policy is to ensure energy security in the form of stable energy supplies in a technically and economically viable manner. The issue of energy security has taken on particular importance in view of the energy crisis in Europe, triggered, inter alia, by Russia's invasion in Ukraine. Almost overnight, Europe faced a threat to the security of supply of strategic energy resources. This situation made Europeans realise the importance of a rational approach to energy policy and energy security.

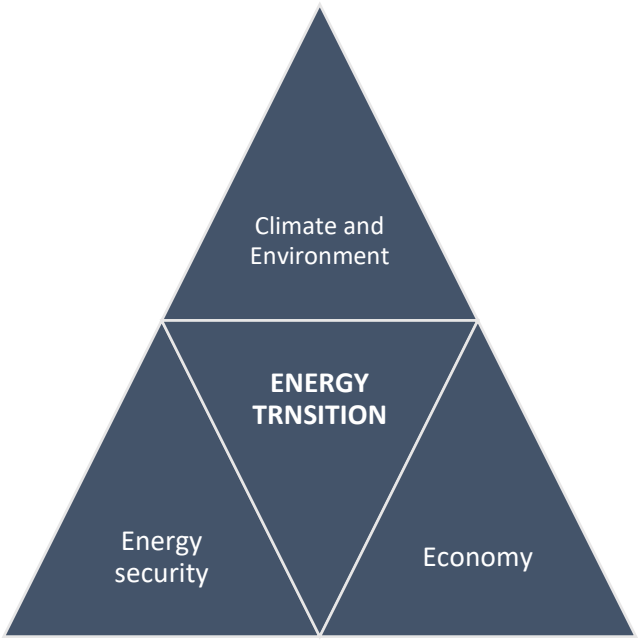
Poland is facing the challenge of energy transition. The overall effort to decarbonise and diversify Poland's energy mix brings to centre stage issues of energy security, which have been further emphasised by the energy and geopolitical crisis consuming Europe. For this reason, it is so important to analyse the factors that make up Polish energy security and aim to maintain it at the highest possible level.

Energy security plays crucial role in not only the energy sector but also in the whole economy. However, there is a lack of a widely accepted definition of energy security – among researchers this concept is blurred (Winzer, 2012, p. 36). There are a lot of papers tackling with the energy security definition, nevertheless there is no consensus on a common accepted definition (Ang et al., 2015, p. 1078-1081). Energy security is highly context-dependent concept, related to the individual country's circumstances, geopolitical issues and development of economy and energy sector (Ibidem). Among the literature, researchers focus on multidimensional nature of energy security concept, emphasising i.e. security of supply, energy availability and energy prices (Spanjer, 2007), (Jamasb, Pollitt, 2008), (Ang et al., 2015), technology, environ-

ment, energy policy and cyber security (Azzuni, Breyer, 2018). Both definition as well as dimensions of energy security are a subject to change as a geopolitical, economic and energy circumstances are dynamically evolving over time (Ang et al., 2015, p. 1078). Definition of energy security is also provided in legal acts. Polish Energy Act defines energy security as "the state of the economy that makes it possible to meet customers' current and future fuel and energy demand in a technically and economically reasonable manner, while complying with the requirements of environmental protection". Thus, it presents the multidimensional nature of energy security concept.

Energy security is a key element of the transition, as highlighted by the Energy Trilemma concept (Heffron et al., 2015). The energy transition encompasses in its scope three key areas: Climate and environment, Economy and Energy Security (Figure 1). Therefore, it is impossible to consider it without taking into account energy security challenges.

Fig. 1. The concept of Energy Trilemma.



Source: Own labour based on the concept of Energy Trilemma
Balanced Energy Trilemma is crucial factor for performing the Energy Transition towards sustainable energy system (Khan et al., 2021, p. 1)

The aim of this article is to present the crucial threats and challenges facing Poland's National Power System, as well as to provide solutions to ensure Poland's energy security over the next 10 years. The research methods used in this article are literature review and data analysis. Article verify the hypothesis that security of electricity supply in Poland may be endangered in the coming years due to, among others, investment gap, coal power plants phase-out and undiversified energy mix.

2. Snapshot of energy security issues in Polish National Power System

The energy security of Poland is the result of the functioning of many interconnected systems. In the context of security of electricity supply, it results from the operation of the generation, transmission and distribution sectors, but also depends on the energy policy pursued. In

recent years, the words "energy security" and "blackout" have been heard more and more frequently in the Polish media. This has to do with the real threat posed by a shortage of generation capacity, which has occurred during periods of heat waves over recent years. The most serious such event occurred in August 2015, when power stages had to be introduced to relieve pressure on the electricity system (Rzeczpospolita, 2015). The current very dynamic development of prosumer photovoltaic installations has to some extent dismissed this threat, however, the stability of the National Electricity System is still dependent on the ability to import energy at critical moments.

Energy security can be threatened in the event of a major failure of a large generation facility or an important component of the transmission network, which may lead to Common Cause Failure (CCF) being a failure of multiple components of a system due to one common cause (Bukowski et al., 2022, p. 10). Such an event occurred on 17 May 2021 when, as a result of a failure at the Rogowiec substation serving the power output of 10 of the 11 units of the Bełchatów power plant, these units had to be switched off and the power system suddenly lost 3900 MW (PSE, 2022). Despite such a serious failure, there was no energy security emergency - the power system operated smoothly mainly due to energy imports from Germany, the Czech Republic and Slovakia, the activation of the spinning thermal reserve in operating coal-fired power plants and the use of pumped storage power plants. It should be borne in mind, however, that the occurrence of such a situation during a heat wave and drought, as well as with a simultaneous shortfall in available generation capacity, such an event could necessitate the introduction of power supply steps and affect the demand side.

The importance of security of electricity supply, which is one of the key elements of national energy security, is reflected in legislation at EU level. The EU, in one of its regulations, created the concept of an *electricity crisis*, which denotes an existing or unavoidable situation of a significant shortage of electricity (European Union, 2019).

The energy transition, which is already happening, is undoubtedly the biggest challenge facing the energy sector in Poland. Moving away from coal, the dynamic development of renewable energy sources and the construction of new gas-fired and potential nuclear power plants is a major challenge, the cornerstone of which is ensuring energy security. A key aspect of the energy transition will be to plan it precisely so that no temporary power shortages arise in the system. In addition, the change in the structure of electricity generation will bring new challenges, such as the need to balance generation from RES or the expansion of the gas transmission pipeline system and the increase in demand for natural gas.

Energy security is also about the supply of fuels and energy resources. A diversified structure of both the energy mix (not allowing a situation of dependence on a single type of energy source) together with diversified sources of supply of fuels and energy raw materials are a critical element of energy security at both national and European level. The current energy and geopolitical crisis has underlined this emphatically (von Homeyer et al., 2022).

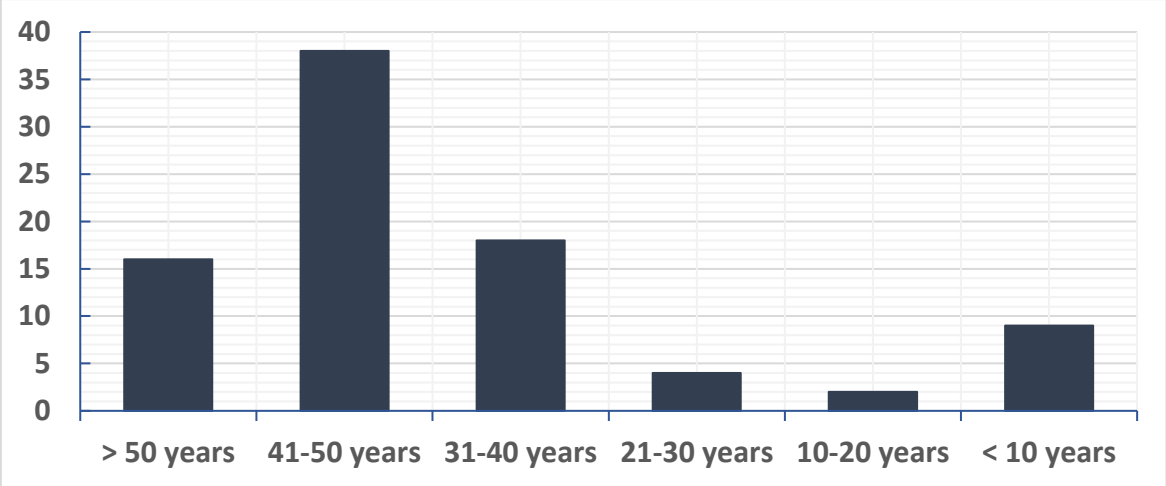
In the following part of this article, the concept of energy security will be largely narrowed down to issues related to the electricity sector only.

3. The characteristics of the biggest challenges facing the electric power system

3.1. Investment gap

The operation of electricity generation assets is largely based on power plants built in the 1960s, 1970s and 1980s. The turn of the century was characterised by an almost disappearance of investments in generation sources. Reasons for this include the privatisation of the energy sector or the political transformation and the economic downturn that followed. This led to a so-called investment gap in the area of generation assets (Krupiński et al., 2019). In fig. 2 shows the age structure of coal units in Poland.

Fig. 2. Age structure of coal-fired units in Poland - the number of coal-fired units commissioned over a specific time period.



Source: Own labour based on the Energy utilities' data

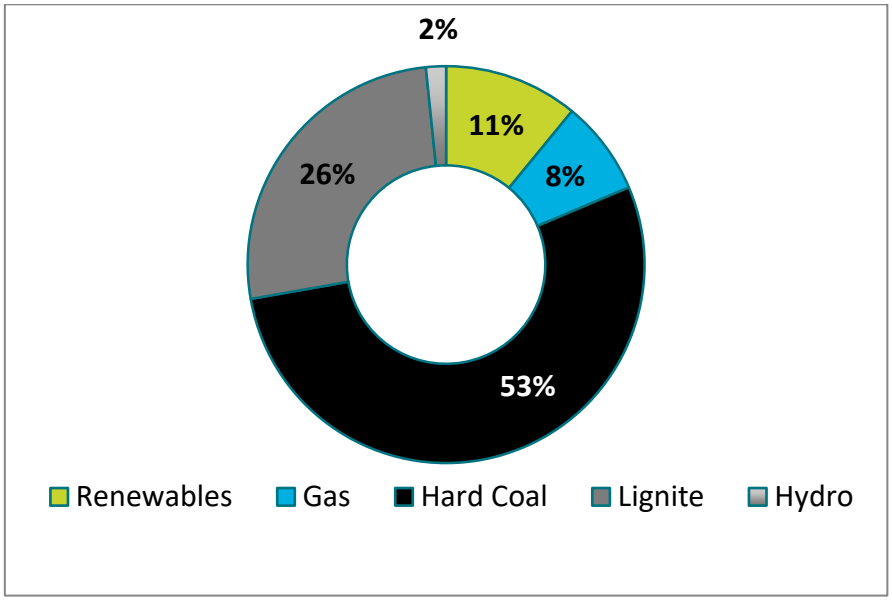
One of the fundamental goals of the energy transition is to fill this gap - that is, to replace the oldest, inefficient and environmentally unfriendly coal-fired units with new, highly efficient combined cycle gas turbine (CCGT) units, nuclear power plants or renewable energy sources (RES). The investment gap means that the Polish energy mix is still based on coal and is unable to be competitive with the energy sectors of most EU countries. The lack of a clear strategy for Poland's energy transition, the insufficient number of investment projects under way, as well as the lack of a precise plan for replacing phased-out coal-fired capacity, make the issue of the investment gap in the area of power generation assets significant.

3.2. Replacement of phased-out coal capacity

Filling the investment gap resulting from the energy transition already underway, however, poses another challenge for the National Power System (NPS) in terms of replacing capacity from obsolete coal units. In view of the withdrawal of such large volumes of installed capacity from the NPS, it is planned to take into operation the units currently under construction, but in the long term there is a real risk of domestic generation not covering the demand for electricity, as alarmed by the Supreme Audit Office (Najwyższa Izba Kontroli, 2019). The threat of domestic generation units failing to cover the demand of electricity consumers is likely to be exacerbated during hot periods, which is related to the high sensitivity of thermal power plants to meteorological and hydrological factors characteristic of heat waves, as was the case in August 2015 when, among other things, the security of electricity supply was threatened. One way to

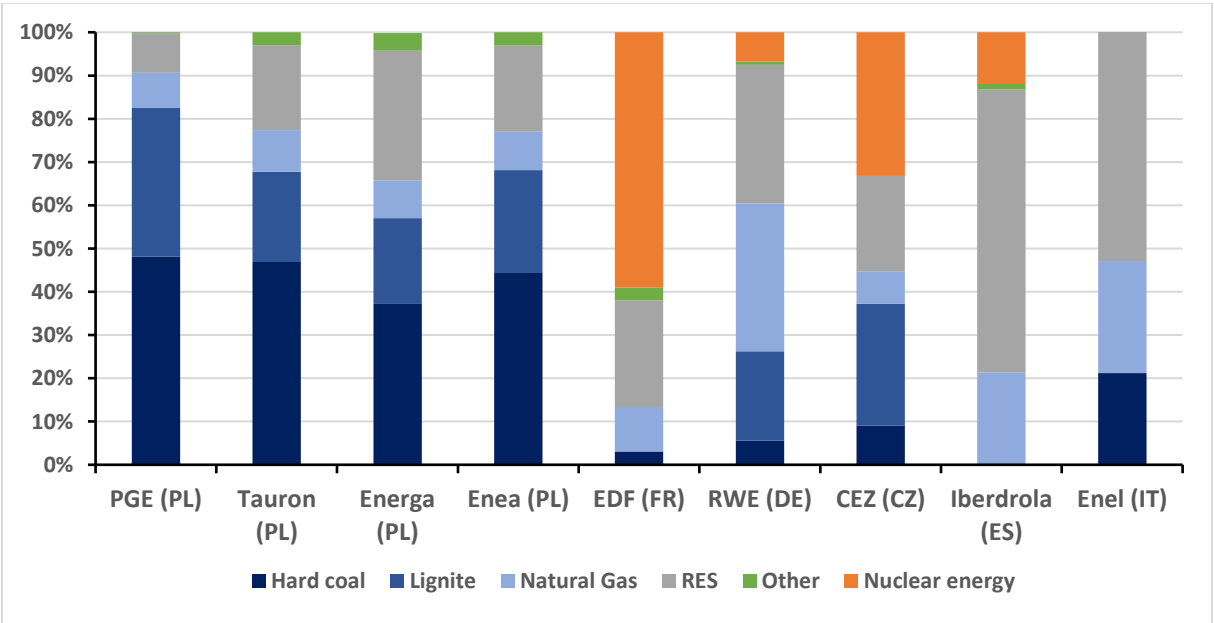
counter this threat was to create a capacity market to provide a financial incentive to undertake much-needed investment in electricity generation assets. It is also crucial to develop a timetable of investments and retirements of obsolete coal-fired capacity so that the system's capacity is not reduced below the minimum values set by electricity demand. The scale of the problem of Poland's generation sector's dependence on coal assets is shown in fig. 3 and fig. 4.

Fig. 3. Polish Energy mix (electricity production in %) as for 2021.



Data source: PSE

Fig. 4. Energy mixes of certain European and Polish energy companies.



Data source: Energy utilities' reports

Electricity production in Poland is based on coal in 79% as in 2021 (fig. 3). The almost total dependence of the power generation sector on coal is highly undesirable, especially from the point of view of energy security as well as exposure to climate risk.

The overwhelming dominance of coal in the Polish energy mix is also reflected in the electricity generation structure of Polish energy companies. The dependence of them on coal ranges from around 65% to as much as over 80% of total installed capacity (fig. 4). This is in stark contrast to companies from other European countries. For example, foreign companies that are characterised by having coal in their energy mix are already at a different stage of the energy transition than Polish companies, and their dependence on coal is much lower. Germany's RWE is about 25% dependent on coal, and the Czech CEZ is less than 40%. In contrast, France's EDF is dominated by nuclear power and Italy's Enel and Spain's Iberdrola by renewable energy. It is therefore crucial to develop a rational decarbonisation timetable that allows for the substitution of decommissioned coal units to ensure energy security. The development of gas-fired power generation to replace decommissioned coal units has been called into question by Russia's invasion of Ukraine and the energy and geopolitical crisis in Europe. This situation has had a not inconsiderable impact on the design of the energy transition in Poland and will be discussed in more detail later in this publication.

An undiversified energy mix based on coal and lignite is undesirable from the point of view of energy security, especially given the problem of obsolete coal assets and the need to phase out the oldest units, as outlined earlier. The situation becomes more complicated especially when there is a sequence of unfavourable conditions affecting coal-fired generating units, which may be emergency stoppages and losses due to meteorological situations (this issue will be further discussed in chapter 3.3). Other risks could be problems with hard coal supply, as well as lignite deposits running out. The first problem became apparent in 2022, after Poland imposed a ban on hard coal imports from Russia, and the second problem will soon become visible in connection with, inter alia, the depletion of lignite deposits supplying Poland's largest power plant in Bełchatów (the expiry date of the mining concession for the Bełchatów Field expires in 2026, and for the Szczerców Field in 2038) (Naworyta, Zajączkowski, 2018, p. 94).

Concluding, the issue of highest priority for the Polish NPS, faced with the threat of a generation capacity gap, is to ensure security of electricity supply and maintain generation capacity at an appropriate level (Ślęzak, 2016).

3.3. Security of electricity supply during heat waves

As already indicated in this chapter, over the last few years, during periods of heat waves (i.e. the occurrence of maximum daily air temperatures above 30°C), there have been situations of threat to the security of electricity supply throughout the country (particularly in August 2015) or in the regions (late July and early August 2018). These resulted from a significant reduction in generation capacity through losses caused by hydrological (low water levels, increased water temperatures in rivers and reservoirs) and meteorological (high air temperature and lack of wind) situations. In addition, at the same time, record summer power demand was recorded, caused mainly by the increasing use of air-conditioning units during summer periods. In addition to the expansion of cross-border interconnections, one important way to address this problem is the dynamic development of photovoltaics, both at the level of prosumer installa-

tions and photovoltaic farms. Currently, the installed capacity of photovoltaics in Poland exceeds 10 GW (fig. 5 in chapter 5). This makes it possible to balance the increase in power demand during midday hours on hot days, improving the operation of the entire NPS. Therefore, the risk of a threat to the security of electricity supply during midday peaks on hot days has now been reduced.

The problem, however, can occur in winter with daily demand peaks on days with unfavourable meteorological conditions for RES generation (cloudy and windless). The spread of heat pumps may lead to further significant increases in electricity demand in winter, which, in the event of a failure in coal-fired power plants, may cause problems in meeting the energy demand of the NPS.

3.4. Capacity of transmission and distribution grids

The problem of insufficient capacity of transmission networks is related to the insufficient number of transmission networks in operation in Poland, especially in the north-south axis. The energy transformation, and consequently the construction of new generation facilities, will require the construction of new transmission lines to take power out of generation facilities and to improve the capacity of energy flow in the NPS. In addition, the expansion of cross-border connections is crucial in terms of increasing import capacity, which in extreme situations is the last resort in stabilising the operation of the NPS in the event of widespread outages. An example of such a situation could be the already mentioned disconnection of 10 units of the Belchatow power plant from the grid on 17 May 2021. The expansion of distribution networks is expected to improve their operating conditions in connection with the growing trend of prosumer energy, electromobility and the development of smart grids. The distribution networks are currently a narrow bottleneck that significantly constrains the possibilities for further RES development, especially prosumer PV installations.

3.5. Energy import as a key element in ensuring security of electricity supply

The planning of the energy transition as well as the country's entire energy policy must be based on ensuring a sufficient level of generating capacity capable of covering the power demand in its totality. Basing the security of electricity supply on energy imports may then lead to a serious threat to the security of electricity supply and, in an extreme case, even to a blackout, as energy imports may not be sufficient in the event of problems in neighbouring countries or if there is a significant drop in capacity on cross-border connections. In the August 2015 in question, the phenomenon of so-called circular flows occurred, which clearly reduced the import capacity in the NPS. A surplus of energy produced in RES installations in Germany flowed through the Polish power system and outflowed towards the Czech Republic and Slovakia. However, investments have now been made in so-called phase shifters on cross-border connections in order to reduce the scale of this phenomenon in the future. Basing the energy mix on hard coal, as presented in the earlier chapters, in the realities of Poland means the necessity of importing hard coal due to insufficient mining in domestic mines. This leads to a certain dependence of energy security on imports of this raw material. Problems with the supply or distribution of this fuel may have serious consequences for the NPS. The shortage of coal on the Polish market that followed the embargo on coal imports from Russia in 2022 proved the necessity to pursue decarbonisation and move away from a coal-based energy monoculture.

3.6. Exposure to climate risk

Climate risk is one of the biggest challenges now facing the energy sector (Kouloukoui et al., 2019, p. 1-2). The Polish power generation sector's dependence on coal means exposure to climate risk. Insufficient diversification of the energy mix and the need for decarbonisation result in high exposure of Polish energy entities to climate risk, which manifests itself in the materialisation of a number of new risks, mostly financial risks. The energy sector is a sector particularly exposed to climate change risks (Burchard-Dziubińska, 2020, p. 161). The new regulations, which are a result of energy and climate policy at both national and European level, aim to phase out energy sources using fossil fuels and develop pro-environmental energy sources. The introduction of the EU ETS CO_2 emissions trading scheme exposes Polish energy companies, which are heavily reliant on coal (fig. 4), to financial risks associated with increases in the price of these allowances. On top of this, entities with coal-fired generation assets in their portfolio, as well as coal and lignite mines, are less well perceived by the market and consumers - in contrast to companies considered 'green', which are more oriented towards sustainable energy development. Climate risk also means the practical impossibility of financing coal power development from international financial institutions or corporate sources of capital due to the aversion of the financial sector to finance coal investments in the era of decarbonisation. The failure to complete the financial assembly and guarantee the investment funds was the reason for the collapse of the project to build the last coal-fired power plant in the EU at Ostrołęka in Poland. Therefore, ignoring climate risk has led to investment failure. Climate risk is the biggest threat to entities that ignore it and do not adapt their strategy to current market reality. (Henderson et al., 2018, p. 10).

4. Poland's energy security in the face of the geopolitical and energy crisis

Russia's invasion of Ukraine on 24 February 2022 created a geopolitical crisis in Europe and clearly intensified the emerging energy crisis (von Homeyer et al., 2022). As a neighbouring country of Ukraine, Poland faced a difficult geopolitical situation due to the ongoing war across its eastern border, as well as a result of its neighbourhood with the Kaliningrad Oblast and Belarus. However, defence-related aspects aside, this situation has had a significant impact on the energy security of both Poland and the majority of European Union countries, mainly due to the previous dependence on imports of energy resources from Russia (Wang et al., 2022). This problem has particularly affected natural gas and hard coal. Poland's energy security after the cut-off of gas supplies from Russia in April 2022 has not been compromised due to a sufficiently diversified structure of gas supplies to Poland, which has been made possible by many years of efforts to become independent from Russian gas, as well as a filling gas storage facilities. The interruption of Russian gas supply to Germany via the Nord Stream pipelines has caused a real threat to the security of gas supply in Germany and has clearly exacerbated the energy crisis in the area of natural gas supply in a significant part of Europe (Bukowski et al., 2022).

A consequence of this situation is also the uncertainty about the further development plans for gas-fired power generation in Poland, which was to fulfil the key role of a so-called transition technology in the energy transition. As an intermediary technology between coal and RES, it was to increase the pace of decarbonisation of the Polish energy sector. However, both the

difficulties in meeting the increased demand for gas and the unprecedented increase in natural gas prices have led to a situation where the further development of gas-fired power generation may be considered unprofitable and unfavourable, both from an economic and energy security perspective.

The energy crisis, also driven by the high inflation, is also manifesting itself in very high electricity prices, especially for industrial consumers and businesses. Among the reasons for this are not only rising prices for energy commodities and fuels, but also a general increase in labour costs or increasing margins by energy companies. This further complicates the energy transition plans and negatively affects the functioning of the whole economy, as well as the pauperisation of the poorest social strata by increasing the problem of energy poverty.

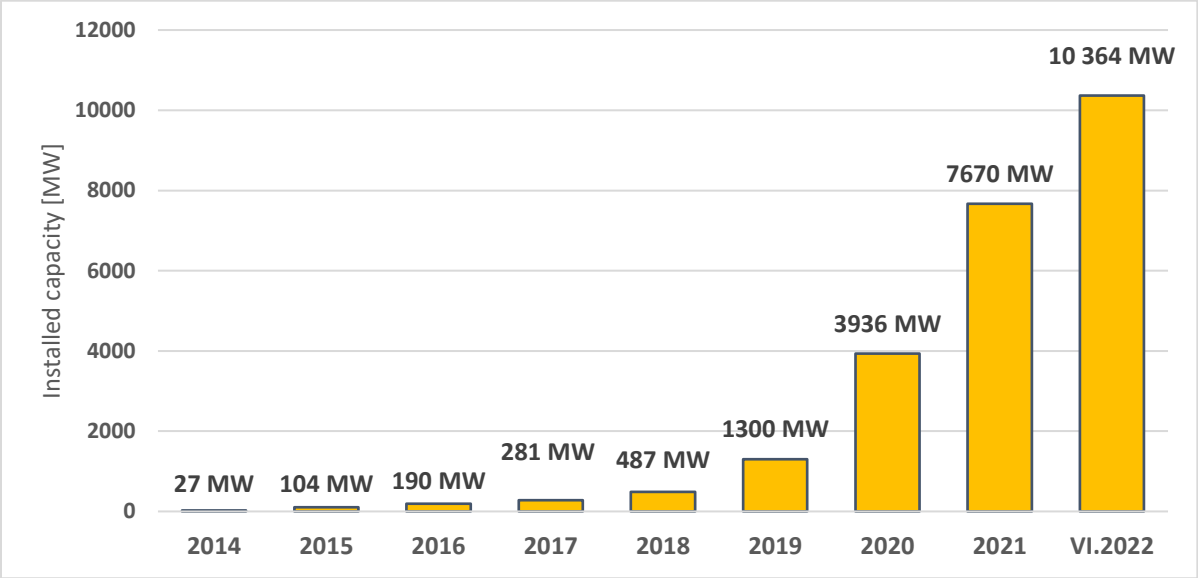
The energy and geopolitical crisis triggered by Russia's invasion of Ukraine has made it clear how crucial energy security is to the economy, and its threat impacts industrial consumers, businesses and individual consumers. Examples include announcements of planned reductions in natural gas supplies in some European countries or orders to reduce indoor temperatures during the heating season. The crisis also forces the question of the state of Poland's energy security in the face of current economic and geopolitical challenges. Furthermore, crisis underlines the necessity of energy transition towards sustainability in Poland (Bukowski et al., 2022).

5. How to ensure Poland's energy security over the next 10 years?

The essential objective of energy policy is to improve energy security (Von Hippel et al., 2011, p. 6727). Over the next 10 years, energy security is to be improved by investment in new electricity generation assets. The construction of new generation facilities is intended to replace outdated coal-fired power plants, whose electricity generation costs make them an economically irrational technology, especially based on the current price of CO_2 emission allowances. The dynamic development of RES (especially onshore and offshore wind power plants and photovoltaics) is expected to ensure the decarbonisation of the Polish energy sector and improve the competitiveness of Polish energy companies through better economic efficiency of these sources. Gas-fired power plants were to be an important element of Poland's energy transition. Natural gas, treated as a transitional fuel, was to facilitate the transition away from coal-fired sources. However, the energy and geopolitical crisis has clearly shaken this concept. Gas-fired power plants were planned to operate mainly as sub-peak and peak load power plants, and their key role was to be balancing a system based on uncontrollable RES. However, from the perspective of both the economic situation and energy security, in the realities of the energy and geopolitical crisis, the approach is characterised by a relatively high level of risk and the need to upgrade some coal-fired units to enable them to extend their operating hours is not excluded. A key element in maintaining energy security, as well as reducing the investment gap and enabling the replacement of phased-out coal units, is investment in nuclear power. Poland needs base load capacity using fuel other than hard coal or lignite covered by the EU ETS. Marginalising the role of natural gas in Poland's energy transition may lead to even greater nuclear investment needs.

An increasingly important source in the Polish energy mix is photovoltaics, which has developed rapidly in recent years (fig. 5).

Fig. 5. Photovoltaics' installed capacity in Poland in years 2014-VI.2022 [MW].



Source: Own labour based on the data: SBF Polska PV, PSE, ARE

Prosumer installations dominate among photovoltaic installations in Poland, mainly due to the 'Mój prąd' support programmes (Krawczak, 2020, p. 14). Such a rapid development of photovoltaics allows the stabilisation of the NPS operation during summer periods and, from the point of view of the users of such investments, is financially advantageous due to the increase in electricity prices. Photovoltaics also have a positive impact on improving energy security on hot days thanks to the high electricity production during midday hours, which balances the increased demand by the increasing number of air conditioners and makes the electricity supply security threat scenarios of 2015 and 2018 much less likely.

Mitigating climate risk will have a significant impact on Poland's energy security over the next 10 years. The risks arising from climate change, as well as the significant pressure from the financial sector on energy companies due to the EU's energy and climate policy, result in coal assets being treated as ballast in Polish energy companies. Energy transition is expected to reduce the risks arising from the negative assessment of companies by external financial institutions and is expected to improve their competitive position in the European market. Decarbonisation in the reality of the energy and geopolitical crisis and high inflation will be a particularly difficult task, taking into account the economic situation as well as Poland's energy security. However, failure to continue the energy transition will result in a lost opportunity for the development and modernisation of the power sector, facing an investment gap in the area of power generation assets (Krupiński et al., 2019).

6. Summary

Poland's energy security, being a multi-component jigsaw that consists of many elements, requires that it be given the utmost attention and treated as one of the strategic elements of both energy policy and overall economic and national security policy. Security of electricity supply in Poland may be endangered in the coming years due to, among others, investment gap, coal

power plants phase-out and undiversified energy mix. The issue of highest priority for the Polish NPS, faced with the threat of a generation capacity gap, is to ensure security of electricity supply and maintain generation capacity at an appropriate level. The energy and geopolitical crisis associated with Russia's invasion of Ukraine has clearly highlighted how crucial it is for the economy to take care of energy security. Energy transition plans and Poland's energy policy need to be revised in the light of the current crisis. Investment in nuclear energy is becoming a necessity in order to cover the investment gap and to ensure the replacement of decommissioned coal-fired power blocks in the face of the serious problems affecting the gas-fired power generation sector. In addition, the challenges associated with the work of the NPS point to the necessity to further expand RES capacity and to continue the process of decarbonisation of the Polish energy sector, which is still strongly dependent on coal. The need to mitigate climate risk is currently one of the biggest challenges facing the energy sector in Poland. According to the Energy Trilemma concept, the energy transition should address energy security and economy aspects as well as climate and environment issues.

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