DOI: 10.24425/academiaPAS.138412

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The Bełchatów power plant in Poland – the largest thermal power station in Europe

Energy Transition Is Necessary and Possible

Is climate neutrality an attainable goal for Poland? What does the term mean, and what challenges does it pose to human civilization? These and other questions are addressed by **Prof. Bolesław Zaporowski** of the Institute of Electric Power Engineering, Poznań University of Technology.

What was the immediate cause for the attention now being paid to the threat posed to humanity by high consumption of fossil fuels?

BOLESŁAW ZAPOROWSKI: In the wake of World War II, in particular after 1950, most countries of the world enjoyed very rapid economic development – driven by a natural desire to recoup the losses suffered both during the war and earlier, during the Great Depression in 1929–1933. This entailed a substantial increase in the consumption of natural energy sources (primary energy), especially fossil fuels such as coal, oil, and natural gas. Their combustion led to a very rapid increase in CO_2 emissions into the atmosphere – from approximately 6 billion metric tons of CO_2 in 1950 to approximately 43 billion metric tons of CO_2 in 2019. Consequently, the equilibrium between the emissions of CO_2 and its absorption by ecosystems was disrupted, and the concentration of CO_2 in the atmosphere rose from 315 ppm (parts per million) in 1950 to 415 ppm in 2019. By comparison, back in 1900, regarded as the beginning of the period of widespread electricity production and use, the emissions of CO_2 into the atmosphere had been about 2 billion metric tons, and the atmospheric CO_2 concentration about 288 ppm.

Initially, the rise in the concentration of CO_2 in the atmosphere and its impact on climate were not widely noticed. It was not until 1988 that the World Meteorological Organization (WMO) and the United Nations (UN) set up the Intergovernmental Panel on Climate Change (IPCC) to examine the problem more closely.

The 14th World Energy Congress, held in Montreal in 1989 with the motto "Energy for Tomorrow," posited that the directions of the development of the energy sector should be considered in three aspects: their energy effectiveness, their impact on the environment, and their economic effectiveness, abbreviated as 3E (efficiency, ecology, economy). The important shift here consisted in adding new aspects alongside energy effectiveness, which had been previously the most important factor.

In 1990, based on an IPCC report, the UN General Assembly adopted a resolution that began the intergovernmental negotiating process to combat climate change. On 9 May 1992, at the UN headquarters in New York, an international team of specialists from 35 countries, including Poland, finished its work on the United Nations Framework Convention on Climate Change (UNFCCC), which was opened for signature on 4 June 1992, during the UN Conference on Environment and Development (UNCED) in Rio de Janeiro. The Convention was signed on behalf of Poland by Foreign Minister Andrzej Olechowski on 21 March 1994 and ratified by President Lech Wałęsa on 16 June 1994. The Convention entered into force on 24 October 1994, and it is a binding international legal act (*Dziennik Ustaw* of 1996, No. 53, Item 238). It starts with words demonstrating that the world's leaders understand the gravity of the problem: "Acknowledging that change in the Earth's climate and its adverse effects are a common concern of humankind (…)."

The Convention's supreme decision-making body is the annual Conference of the Parties (COP). At the cyclical COP meetings, governments meet to discuss the content of documents determining the implementation of the obligations arising from the Convention by individual countries. Its primary goal is to stabilize the concentration of CO_2 in the atmosphere at a safe level. So far, there have been 25 such conferences, from 1995 to 2019 (2020's meeting was cancelled due to the COVID-19 pandemic). Representatives of governments are scheduled to meet at the 26th conference in Glasgow in late 2021. Poland has already hosted three Conferences of the Parties: COP 14 in Poznań in 2008, COP 19 in Warsaw in 2013, and COP 24 in Katowice in 2018. The most important decisions were taken at COP 3 in Kyoto (1997), where the Kyoto Protocol was adopted, and at COP 21 in Paris (2015), where the Paris Agreement was reached.

The Kyoto Protocol required the countries that ratified it to reduce their greenhouse gas emissions below a certain "base level" over 2008–2012. This base level was determined by the emissions in 1990 for

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most countries, and in 1988 in Poland's case. Poland obliged itself to reduce its emissions by 6% against that level. The Kyoto Protocol entered into force on 16 February 2005. By the end of 2005, the document had been ratified by 157 countries, which thus became parties to the Protocol. It was the first step towards proper international negotiations on climate change. However, the world had to wait for their outcome until COP 21, held in Paris in 2015 – when the first-ever universal, legally binding climate agreement was concluded. The deal stands a chance of protecting the world against the effects of climate change. Its implementation is expected to curb the average rise in the Earth's temperature to below 2°C compared with pre-industrial levels. However, efforts are being made to prevent this rise from exceeding 1.5°C. In Europe, observations, data collection, and analyses in the field of climate change are carried out by the EU's Copernicus Climate Change Service (C3S), among other frameworks. The findings and data are utilized by such institutions as the European Centre for Medium-Range Weather Forecasts (ECMWF). The Copernicus Climate Change Service has reported that 2020 (along with 2016) was the warmest year since records first began to be kept, and the average temperature on Earth in that year was 1.25°C above the pre-industrial levels.

> Most countries, including the EU member states, intend to reach climate neutrality by 2050.

The Paris Agreement was adopted by 196 countries by consensus on 12 December 2015, the last day of the Paris Conference. Poland signed the agreement at the UN Headquarters in New York on 22 April 2016, and the Sejm passed an act to ratify it on 6 October 2016. The agreement entered into force on 4 November 2016, following its ratification by 55 countries, accounting in total for over 55% of global CO_2 emissions. Before COP 21, countries submitted plans to reduce CO_2 emissions by varying amounts. At later conferences, however, they were unified in the form of a commitment to reach climate neutrality, or a state of equilibrium between CO_2 emissions and absorption. Most countries, including the EU member states, intend to reach this status by 2050. Globally, this means reducing CO_2 emissions from the current level of about 43 billion metric tons to about 4.5 billion tons in 2050. Countries are expected to achieve this goal by reducing CO_2 emissions substantially in all areas of transportation, industry, and agriculture and to zero in electricity generation and almost zero in heat generation. In 2019, electricity generated from coal accounted for more than 73% of all electricity generated in Poland, compared to only about 15% in the case of renewable sources.

We already know that the energy transition is necessary not only due to climate goals and commitments, but also because of market requirements. Do you think such transformation is possible?

The answer to this question depends on what part of the planet we are referring to. The Paris Agreement refers to the whole of the world. The condition of the power generation sector in different regions of the world varies and remains closely linked to the economic situation of those regions and their natural resources (primary energy sources). The condition of the power generation sector in individual countries is best characterized by their national energy systems. Every year for the past 10 years, the World Energy Council has rated the performance of national electric energy systems in more than 130 countries of the world using three criteria: energy security (the security of energy supplies), energy equity (ease of access to electricity as gauged by electricity prices in relation to *per capita* national income in each country), and environmental sustainability (the impact on the environment).

The top-ranking country in the 2020 ranking list was Switzerland, followed by Sweden. In 2019, 98.8% of electricity in those countries was generated from zero-emission sources, including 30–40% in nuclear power plants. Ranking next on the list are France, Brazil, Finland, Canada, Slovakia, Belgium, Slovenia, Hungary, and Spain. The share of electricity from zero-emission sources in these countries ranges from 59.2% in Spain to 88.8% in France. The energy transition in those countries should be relatively swift and should not generate very high costs.

The 2020 ranking of electric energy systems put Poland 41st in the world and 26th in the EU (followed only by Cyprus). This indicates that the energy transition in Poland will be a long and capital-intensive process. An additional difficulty is posed by the fact that while Poland is a major producer and consumer of electricity (ranking fifth in the EU and 25th in the world), in fact we lag behind in this area, because in terms of economic potential measured by annual GDP Poland actually ranks higher, at 21st in the world.

Energy transition is possible in Poland, but this transformation will require significant funding for the development of zero-emission electricity generation technologies. That said, we should bear in mind that the economic situation of many countries in the world is much worse, and Poland can additionally count on

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Offshore wind farm

assistance under the EU's "just transition" framework. As is the case with other EU countries, this should help us to successfully transform our energy sector. On a global scale, as part of the solidarity policy, the Paris Agreement provides for the establishment of a special fund to assist developing countries in their energy transition. At the beginning of 2020, however, Poland was already classified as a developed country.

What technological conditions have to be met in the energy sector, for Poland to be able to attain climate neutrality?

The most important issues that have to be resolved in the coming months for the door to climate neutrality to open up for Poland are to implement "The Energy Policy of Poland Until 2040," adopted by the Government on 2 February 2021, and to reach agreement with the European Commission on the "National Energy and Climate Plan for 2021–2030," submitted to Brussels in December 2019. These documents set forth a path for the long-term strategy of building a safe and zero-emission electric power system, ensuring the country's electricity supplies security, and making major reductions in CO_2 emissions in all branches of the economy. This problem is addressed in the "Opinion of the Committee on Electrical Engineering, Polish Academy of Sciences, on the implementation of nuclear energy in Poland." It argues that given the lack of sufficient hydropower sources in Poland able to support the construction of major hydroelectric plants, building a secure and zero-emission electric power system has to be based on renewables and on zero-emission nuclear power plants. Poland's attaining climate neutrality around 2050 will be possible if the decisions are made, among other things, to build a secure and zero-emission electric power system, and to make major reductions in the CO_2 emissions in heat generation, transportation, and all branches of the industry and agriculture.

Apart from its reliance on coal, how else does the Polish energy market stand out from the rest of Europe?

If we understand the energy market broadly, as a sector of the economy that deals with generating and supplying electricity and heat for industry, transport, services, and households, as well as fuels for land transport and aviation, the Polish energy sector has several distinguishing traits as compared with the rest of Europe. The first of these is the subsector of generating and supplying heat. All the large and medium-sized cities in Poland, most of the small ones, and also many industrial facilities have their own district heating schemes, which together comprise the National District Heating System. In a district heating scheme, heat is generated centrally, then supplied to end-users by means of a district heating network. In most other European countries, individual heat generation is predominant.

Heat that is centrally generated and supplied to end-users by means of a district heating scheme is known as network heat. Each year, the amount of system heat generated in Poland is around 480,000 TJ, in other words around 133.3 TWh. In 2019, for instance, the figure was 475,477.8 TJ (132.1 TWh). Around 65% of the system heat in Poland is co-generated in conjunction with electricity. For a thermal system to be described as energy-effective, the amount of heat co-generated together with electricity should be at least 75%. Potentially, 50% of system heat should be generated from renewable energy sources. The co-generation of electricity and system heat takes place in what are called cogeneration power units, which function simultaneously in the National Electric Power System and in one of the hundreds (around 400) of separate district heating systems, of varying thermal power. Cooperation between the National Electric Power System and the National District Heating System places additional demands upon the for-

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Nuclear power plant

mer in terms of operating continuity and stability, and hence security. The most important criterion for the functioning of a cogeneration unit is operating at a level of thermal power generation that is consistent with the demand for thermal power in the district heating system, which in most types of cogeneration units also requires working at the proper level of electric power generation in the National Electric Power System. This demands that the electric power being generated at other units operating with in the National Electric Power System be regulated so that the sum of the electric power of all the generation units is at every moment equal to the demand for electric power.

Moreover, the Polish Electric Power System has relatively poor network links to the power systems of neighboring countries, which in emergency situations poses an obstacle to utilizing their assistance.

The Polish energy sector unfortunately stands out against the European backdrop also in terms of the quite antiquated generation units operating at its power plants and combined heat and power (CHP) plants. Of the 91 hard coal and lignite fired steam units at the power plants, as many as 41 have been operating in the National Energy System more than 40 years. The cogeneration steam units at the CHP plants have been in operation for even longer on average. The past 30 years have seen little continuity in efforts to renew the infrastructure of generation units. After 1988, there was a certain interruption in the process of building new power plant units, which lasted all the way until 1994. In 1994–1997, four new units were placed into service at the Opole power plant. After this investment, there was again an interruption until 2008, when a new steam unit with supercritical parameters was placed into service at the Pątnów power plant. In the past 12 years, only six steam units with supercritical parameters have been placed into service. This discontinuity in investing in generation sources in the Polish power industry has caused a disruption in the regular aging process of power-generation units and their being taken offline, and also the occurrence at certain times of shortages of available power in the National Power System, especially from centrally dispatched generation units (CDGUs). At present we are now facing a culmination in the aging of generation units and a need to take a large number of them offline within a short period of time. The energy transformation of generation sources in the Polish electric energy industry is therefore necessitated not only by the emerging problem of climate change, but also by the aging of the existing power generation infrastructure.

Another trait that distinguishes the Polish power sector from the sectors of most European countries is the relatively low *per-capita* electricity consumption, even compared with countries with similar national incomes. In the EU Member States, this figure was 6305 kWh in 2019, as compared with 4477 kWh in Poland. The highest *per-capita* consumption was seen in Sweden, at 16,779 kWh. This, too, could cause give rise to increased demand for electric power in the National Electric Power System in the coming years.

Are there any technological limitations to adding nuclear power into Poland's energy mix?

Implementing nuclear power in any country poses a major technological, economic, and developmental challenge. The related problems were more serious in the initial period of its development in the world, more specifically in the latter half of the twentieth century. With more than 440 nuclear power units now operating across the world with total capacity of more than 493,390 GW, we can talk about there being considerable experience in constructing and operating of nuclear power plants. Over the past 20 years, modern and safe generation III+ pressurized water reactors (PWR) have been designed, and experience has been gained on how to best construct and use operate them.

These external conditions are favorable for Poland, which is preparing to introduce nuclear power. However, the domestic industry and industrial construction sector are faced with the great responsibility of preparing for tasks related to implementing the nuclear power program. About two-thirds of the related investment tasks can be performed by Polish companies. This holds true in particular for many construction tasks related to laying the foundations for the reactor and the turbine building, the containment building, and the cooling system. Such tasks can be successfully

completed by Polish construction companies, such as Polimex-Mostostal SA, Mostostal Warszawa SA, and Budimex SA, which are highly qualified and experienced in constructing 1000 MW power units. In addition, we have considerable design and construction potential when it comes to the steam generators at Rafako. Ensuring the safe operation of nuclear power units is a new task that requires many years of preparations. In my opinion, our country's technological, economic, and developmental level and the size of the National Electric Power System will allow Poland to perform these tasks with success.

Are today's renewable energy production and distribution technologies enough to ensure energy security for inhabitants of Poland and its industry?

It is the responsibility of the state to ensure the security of electricity supply to industry, transport, services, and households. To fulfill this obligation, the state must have an efficient and secure National Electric Power System. In this new energy reality, which started with the adoption of the Paris Agreement by almost all countries, modern electric power systems must meet three criteria, namely: the security of electricity supply, moderate electricity prices (which depend on low production costs), and environmentally sustainable electricity production. This means that a modern electric power system must be characterized by high operational safety, zero-emission electricity sources, and high economic effectiveness. In other words, such a system must be safe, produce zero emissions, and provide electricity to consumers at possibly low prices. This is exactly the electric power system that must be built in Poland within the next 30 years.

Is it possible to build such a system based exclusively renewable energy sources? The PAS Committee on Electrical Engineering has concluded that this goal cannot be achieved in the required time frame in light of the natural conditions in Poland and the absence of significant hydroelectric power resources.

For the purpose of generating electricity, both Poland and most countries now use – and will continue to use in the future – primarily wind and solar energy, whereas hydroelectric energy and biomass are used to a much smaller extent. Electricity sources that use wind and solar energy as primary energy are characterized by relatively low utilization time of nominal electrical capacity (capacity factor values). In the meteorological conditions that prevail in Poland, these values are as follows: about 3400 hours per year for offshore wind power plants, about 1900 hours per year for onshore wind power plants, and about 950 hours per year for photovoltaic power plants. If the electric power system only had power plants with these continuity parameters, it could not supply consumers with electricity in a continuous way (without disruptions). The difficulty lies in storing electricity in amounts that will allow the electric power system to work in a safe and stable way. This can only be achieved through the conversion of electricity into other forms of energy, preferably hydroelectric or chemical energy, in the form of pumped-storage hydroelectric power plants or electrochemical or hydrogen storage facilities. Building pumped-storage power plants requires natural conditions suited for the construction of upper and lower reservoirs and considerable financial resources. In the case of electrochemical energy storage facilities, especially hydrogen storage facilities, the energy losses in multiple energy conversion processes and the cost of the equipment needed for energy conversion mean that, for the purposes of cooperation with the electric power system within the time limit required for the energy transition, they will not, in my opinion, reach commercial maturity, especially when it comes to the criterion of economic effectiveness. On the other hand, electrochemical storage technologies have already been used in transport and, to a lesser extent, in electricity distribution networks. In addition to being used in industrial technologies, hydrogen technology is making its way into transport. In the future, this technology may also be used in distributed energy systems. For now, therefore, no industrially developed country with similar natural conditions as Poland intends to build a secure zero-emission power system using only renewable energy sources. The one exception is Germany, which nonetheless intends to a considerable extent to use power plants fired by natural gas. Its use for electricity generation purposes causes emissions at the level of 45% of CO_2 emissions from coal-based sources – in other words, this is not a zero-emission technology. Large water energy resources are the only renewable energy source that would allow the electric power system to operate in a continuous and safe way. But Poland does not have such resources. In Europe, such conditions can be found in such countries as Norway.

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Interview by **Justyna Orłowska, PhD**