Konrad Hennig

National ownership of power generation technology as an element of the energy security of Poland

Energy security of every single state is contingent on shaping the energy balance ensuring the utmost resilience against the following factors: 1. external attacks (achieved by the dispersion of generator installations); 2. system crush (by mastering technologies); 3. disruptions in energy sources supply (by achieving self-sufficiency or diversification of sources and transporting channels). In the politicians' perception the notion of energy security boils down merely to energy independence to be achieved via the maximising the energy sources derived from their own territory. The reliance of the domestic energy balance on available original energy sources in a given country is definitely the first step towards a responsible energy policy. No less important, however, though often overlooked, is the exploitation of one's own technologies of sources acquisition and power production. Given the continually growing challenge of rapid technological advancement constituting the object of competition between super-powers (with cyber security and economic security taking the lead) the issue of energy security becomes an overriding element of a public debate. The energy security comprises four component parts i.e.: 1. independence in obtaining energy sources; 2. the stability of electricity networks and the transport of fuels; 3. diversification of sources of foreign energy resources supplies and of the sources of energy production within the state; 4. technological independence, i.e. the state ownership of energy production technologies, to be discussed further in the present article.

The level of energy independence, calculated as a share of energy produced from domestic sources in the total energy consumed for the five selected EU countries:

Table 1. Degree of energy independence.

2014 data in thousands of tonnes	Germany	Spain	France	UK	Poland
General consumption of energy	306 753	114 559	242 642	179 421	94 018
General acquisition of energy	120 713	35 101	137 128	108 236	67 326
Degree of energy independence	**0,393519**	**0,306401**	**0,565145**	**0,603252**	**0,716097**

Source: „Energy Balances of OECD Countries", IEA.

As the above data show, Poland has a relatively high degree of energy independence, due to a proportionate exploitation of hard coal and brown coal, covering ca. 30% of the domestic need, to the needs of our economy, as well as extraction of natural gas.

"*The most important energy carrier is hard coal (60,6% in 2015). The second carrier in terms of volume of extraction was brown coal with the share of 17,9%. The share of natural gas in the whole extraction was 5,4%, crude oil 1,4% and the rest, mostly renewable energy carriers 14,7%"*. In turn *"the most important consumed carrier was hard coal with its share of 39,5%. The share of crude oil was 25,1% and natural gas 14,0%. Brown coal was 11,6% of the consumed energy and other carriers were 9,8%.*[1]" Can we therefore acknowledge with satisfaction that as a country we enjoy a basic level of energy security?

In terms of statistics the above question could get a positive answer. However, we have to bear in mind that security cannot be perceived as a state but a set of diachronic processes. Variability of phenomena in time, particularly in view of their complexity and mutual correlation makes us see challenges and threats as a highly dynamic phenomenon. Minor processes unfolding today on a small scale may grow geometrically in a short term perspective, threatening the stability of electricity system or fuel system. In view of this, we need to be very cautious in deriving optimism from the extrapolation of past experiences concerning electric system based on coal-burning.

The government policy in recent years has put much emphasis on a diversification of liquid fuel supplies (gas in particular), while at the same time the Polish power generation system fails significantly in terms of flexibility in 5 basic categories: 1. administering of deliveries; 2. demand shaping; 3. storing; 4. obsolete networks, and 5. the structure of the wholesale, balancing and retail market.[2] It is therefore exposed to the loss of dynamic stability (the risk of lowering voltage: *brown-out*, the risk of cutting voltage: *block–out*) as a result of energy imbalance between energy produced at a certain time and the volume of energy transformed in appliances and energy lost during the transmission. To provide the system with more flexibility, we need more international connections, power depots, and the domestic available reserve power. The coal facilities providing a base in producing power are partially flexible but their phasing out entails the high risk of damages and accidents, and the work on full capacity is dependent on cooling water availability. The gas installations available only in heating segments, municipal and industrial cogeneration show the highest flexibility. The wind and PV installations are dependent only on weather conditions and cannot be disposed as per the requirements of the National Electrical System (Krajowy System Elektroenergetyczny). The increase of their share in the electric mix leads to a further exacerbation of a poor flexibility of the system. Only a few of pomp-storages in Poland feature higher flexibility (response in 2–3 minutes) and are capable of storing power. Given that, the suspension in late 1980s of the construction of Elektrownia Wodna Młoty (750 MW), followed by its sale to Électricité de France may

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[1] *Gospodarka paliwowo-energetyczna w latach 2014 i 2015*, Główny Urząd Statystyczny, Warszawa 2016, http://stat.gov.pl/download/gfx/portalinformacyjny/pl/defaultaktualnosci/5485/4/11/1/gospodarka_paliwowo_energetyczna_2014_2015.pdf [access: 12 VI 2017].

[2] I. Kielichowska, E. Haesen, T. Sach, *Flexibility Tracker Country Report Poland*, http://www.leonardo-energy.org/resources/503/flexibility-tracker-country-report-poland-5814f41cb7050 [access: 12 VII 2017].

be somewhat surprising. The unfinished power plant was returned to Polish Polska Grupa Energetyczna S.A. thus the feasibility study concerning the costs of its completion may be expected soon. The only alternative location enabling the construction of a comparable scale power plant of comparable scale is the external soil bank by the Bełchatów Brown-Coal Mine. At present there are 6 pump-storage plants in Poland: Żarnowiec, Porąbka-Żar, Żydowo, Solina, Dychów, Niedzica. They all are capable of storing 10 GWh and their installed power equals 1 700 MW.

Consequently, just like few decades ago, the flexibility of the Polish power system is based on power supply levels, that is, on the flexibility potential of power customers rather than producers. The introduction of a chargeable limits on the consumption of power by selected customers DSR (Demand Side Response) helps to overcome political costs resulting from the introduction of the power supply levels (mid-2018 ca. 500MW[3]), but does not change the overall reasoning. Additionally, "*transmission networks are old and overburdened: more than 80% of 220kV networks, 56% of 400kV networks and 34% of sub-stations are over 30 years old; also in case of distribution networks their average age is more than 30 years.*"[4] The market of energy purchases by wholesale customers is based on forward contracts and a day-ahead market. We are only in the eve of shortening time slots to make prices more flexible and to steer the needs of industrial customer for power.

Ensuring energy security by making electric networks more flexible requires the implementation of the whole range of technological solutions, few billion zlotys' worth investments and the update of legal regulations. The awareness of the above needs is being raised by tech companies, which attempt to attract decision makers to their products and computer solutions. As a result of close ties and cooperation between energy sector and industry and the necessity to address the requirements of economy, one can hope that the negligence of the past three decades can be overcome at a faster pace than in the case of technical modernisation of the Polish Military Forces.

The energy independence and stability of power networks, however, is only a part of the problem. The diversification of domestic electrical power sources is of no less importance. The structure of our energy balance is the aftermath of decisions taken by the communist Soviet decision makers. In 1990 the power production was based in 98% on burning coal in public plants and thermal power stations, and in 2% on hydropower plants. Hard coal was then a source of almost 70% of conventional energy and brown coal of almost 30%. Even though our own resources were solely exploited at that time, that was not an optimal solution from the perspective of system security. As in any monoculture it exposed our entire electricity system to the risk of fluctuations in the coal sector (e.g. the increase in material prices or introduction of the EU anti-coal policy). To date we have been limiting the share of coal to 86% in the market, although some part of the remaining 14% makes up for a co-incineration of biomass in coal

[3] https://www.pse.pl/uslugi-dsr-informacje-ogolne [access: 8 VI 2018].

[4] *Elastyczność w energetyce – wyzwania stojące przed Polską*, http://nowa-energia.com.pl/2017/03/30/elastycznosc-w-energetyce-wyzwania-stojace-przed-polska/ [access: 20 VII 2017].

installations. Still, we cannot boast a proportionally diversified energy balance, in which a share of various 4-5 sources makes up 15-30%, which seems to be an optimal solution.

The development of domestic energy balances in the world was a result of the long-time processes influenced by a range of endo- and egzogenous factors. The percentage share of renewable energy, atomic energy, coal energy or gas energy differed among countries and were conditioned on the particular circumstances. The energy mix in a given country was predominantly determined by its topography, water supplies, raw materials supplies, geopolitical situation and the stage of technological development. Consequently, the primary energy balance as well as the structure of power generation and the exploitation of fuels in urban and domestic sector can significantly differ between very similar and neighbouring countries, since it may only be one factor that disturbs radically the contribution of each energy source.

It should be noticed that the structure of energy production for a particular country is relatively stable. The processes of a deliberate transition towards other energy sources take years (planning and construction cycle of a conventional power plant lasts from 5 to 12 years, its construction generates significant costs, and in case of the change in balance occurring in a medium-sized state more than one power plant is needed) and are motivated usually by a discovery of more effective energy sources on site, for example by launching an extraction of thus far undetected resources of raw materials or developing new technology (or otherwise the withdrawal due to natural or anthropogenic catastrophes). With most changes, the new sources instead of replacing the previous ones, triggered a growing demand of the economy for electric power. The examples of such deliberate changes are Japan[5] and Germany, which chose to gradually phase out nuclear power plants until 2022. It seems that Polish energy transition is not likely to be so radical and the introduction of a new power generating source will proceed in response to a growing demand. What kind of source will be chosen by the Polish government, remains to be seen. The question will reoccur later in the text.

From the economic point of view the energy balance is a function of availability and the cost of power production. In case of Poland the accessibility of various energy sources can be classified into three segments:

Table 2. Availability of energy sources in Poland.

High	Hard coal, brown coal, solid and liquid bio-fuels (plant and animal solid waste, solid and liquid industrial waste, urban waste, biogas from dumping sites and purification plants), geothermal energy.
Average	Natural gas (including shale gas), wind energy.
Small	Crude oil, water energy, nuclear energy, solar radiation.

Source: private study of the author.

[5] In Japan, several years after the catastrophe in Fukushima we can notice a gradual moving away from such radical decisions. J. Malko, *Energetyka japońska. Jak radykalna transformacja?*, Energetyka, no. 6/2013, http://www.cire.pl/pliki/2/energ_japonska.pdf [access: 18 VIII 2017].

The sources broken down by unit production technical costs:

Table 3. Individual technical costs of power production in Poland (PLN/MWh).

	2012	2013	2014	2015
Brown coal	139,7	134,6	134,9	130,4
Water energy	186,2	153	170,5	164,2
Hard coal	212,5	199,3	183,9	172,3
Wind energy	208	222,1	227,8	210,9
Natural gas	303,1	372,2	261	241,2
Biomass	446,1	405,6	361,6	367,9

Source: Z. Kasztelewicz.[6]

The above data show that in our case economic factors favour the use of brown coal, hard coal and water energy and affect the limited use of natural gas and biomass. The Polish energy mix lacks nuclear power, and the solar energy or geothermal energy occur in trace amounts, because their exploitation generates even higher costs. The economic criteria, however, are not decisive in a decision-making process. They should obviously be taken under consideration in the context of a slump in international competitiveness of energy-intensive sectors of the economy accompanied by a high price of the energy but the energy policy of the state should take into account other factors alongside the economic efficiency. From the perspective of the energy security both geographical and technological factors come into play i.e.: the availability of the energy sources and mastering of the power generating technologies by a domestic industry. We cannot speak about energy independence only on the grounds that we have energy sources (fossil or renewable) at our disposal. It is only possible after business undertakings and the S&R institutions acquire the know-how in the field of the entire process of development of the extraction and generating facilities and the production of the relevant machinery.

Domestic business enterprises (duly registered, taxpayers, carrying out production and R&D activity, state-owned or citizens-owned) in Poland are able to realise projects of minerals extraction from the existing conventional deposits: hard coal, brown coal, crude oil, natural gas and geothermal energy. We are a significant solar panels producer (heating of water storage tanks) and we are achieving remarkable progress in the development of wind energy technologies (also at sea), even though the key elements (wind turbine and generator) are still supplied by foreign contractors. Mastering of power generation technologies looks slightly bleak. Despite the fact that our installations benefit from the production capabilities based on hard coal, brown coal and water energy, major investments in the past few years have been frequently carried

[6] Z. Kasztelewicz, A. Tajdus, T. Słomka, *Węgiel brunatny to paliwo przyszłości – czy przeszłości?*, Węgiel brunatny gwarantem bezpieczeństwa energetycznego, Kraków 2016, p. 237.

out by foreign companies or consortia of domestic and foreign companies, where the key technologies were delivered by Siemens, Hitachi, Mitsubishi, or General Electric. The following table presents a set of the most important upgrading and investment in producing installations.

Table 4. Contractors of selected investment projects aimed at enhancing generation capability.

Year/s of investment	**Investor**	**Location**	**Contractor**
1	**2**	**3**	**4**
1995-2004	Żarnowiec S.A. Hydroelectric Power Station	Żarnowiec	Westinghouse WDPF 2 System Brüel&Kjœr Compass System MCM and IRIS HydroScan System Automative System of Technical Control over Dams by Budokop Sp. z o.o.
2013-2017	Orlen S.A.	Włocławek Industrial Cogeneration Plant	Steam and gas block by General Electric and SNC Lavalin
2012-2014	Jastrzębska Spółka Węglowa S.A.	Przyjaźń Coking Plant in Dąbrowa Górnicza	General contractor: Energoinstal. Siemens Wind Turbine Generator System
2011-2013	KGHM Polska Miedź S.A.	Głogów Cogeneration Plant, Polkowice Cogeneration Plant	Steam and gas block by Energoinstal
2004-2011	PGE S.A.	Bełchatów Power Plant	Consortium of General Electric, Alstom and Rafako; the construction of the supercritical brown coal fired unit
2014-2017	Spółka Energetyczna Jastrzębie SA	Zofiówka Cogeneration Plant	Cogenerational Fluid Block by the consortium of Energoinstal S.A. (80%) and Przedsiębiorstwo Budownictwa Ogólnego Skobud (20%).
2013-2017	PGE S.A.	Gorzów Wielkopolski Cogeneration Plant	Steam and gas block from Siemens Sp. z o.o. and Siemens Industrial Turbomachinery AB
2012-2017	Enea S.A.	Kozienice Power Plant	The construction of the supercritical coal fired unit by the consortium of Polimex-Mostostal and Hitachi Power Europe.

2015-2018	Fortum	Zabrze Cogeneration Plant	Alternative fuel, coal and biomass cogeneration block. Chief engineer of the contract ILF Consulting Engineers. Fluidal beds circulatory boilers by Amec Foster Wheeler. Turbine set, generator and heat exchangers system by Doosan Škoda Power. Xternal coal and alternative fiel feed system by BMH Technology. Steel construction from Mostostal Zabrze. Construction Works by Budimex S.A.
2014-2019	PGE S.A.	Turów Power Plant	Brown coal block from the consortium of Mitsubishi Hitachi Power Systems Europe (55,38%), Budimex (22,31%) and Tecnicas Reunidas (22,31%).
2014-2019	PGE S.A.	Opole Power Plant	Consortium of Rafako, Polimex-Mostostal and Mostostal Warszawa. Ultra supercritical block by General Electric. Two BP boilers by Rafako company. Generators and steam turbines of ultra critical parameters, boilers, power plant auxiliary systems and environment installations by Alstom company.
2014-2019	Tauron S.A.	Jaworzno Power Plant	Consortium of Rafako (99,99%) and Mostostal Warszawa (0,01%). Turbine by Siemens.
2014-2016	Zakłady Azotowe Kędzierzyn	Kędzierzyn-Koźle-Cogeneration Plant	Complete cogeneration installation from Rafako company

2012-2019	Tauron S.A. PGNiG Termika	Stalowa Wola Cogeneration Plant	Contract with general contractor Spanish Abener Energia company broken in 2016. Gas turbine by General Electric and gas turboset by Skoda Power. Construction in the EPCM formula (Engineering-Procurement-Construction-Management) finishes the consortium of Zakłady Pomiarowo-Badawcze, Energetyka Energopomiar and Energoprojekt-Katowice.
2017-2020	PGNiG Termika	Żerań Cogeneration Plant	Cogeneration gas and steam Block from the consortium of Mitsubishi Hitachi Power Systems Europe Gmbh, Mitsubishi Hitachi Power Systems Ltd, Mitsubishi Hitachi Power Systems Europe, Polimex-Mostostal.

Source: private study.[7]

The existence of domestic specialisations was explicitly indicated in *The Programme for the Hard Coal Mining Sector in Poland* of 2016 (...): *"Poland does have a developed mining sector, including mining machinery and equipment. Domestic companies producing mining machinery and equipment are private, often listed on the Warsaw Stock Exchange. The majority of the companies is based in the southern Poland. It should also be pointed out that Polish sector of mining machinery is very diverse. The machinery for mining mineral resources, sections of mechanized housing, conveyors (belt and scraper), machinery for transportation, security machinery, drilling equipment, electrical wires, transformers and pumps, working clothes are continuously produced. The Polish brand is a household name appreciated for its quality. At present the export goes mainly to Russia, China, Mongolia, Kazakhstan, Australia, Indonesia, India, Canada, USA, Argentina, Columbia, Ecuador and Congo. The national producers are recognized on all the continents, where mineral and energy resources are mined in opencast workings and other methods."*[8]

[7] Based on press materials of the companies and *Budowane i planowane elektrownie*, http://www.rynek-energii-elektrycznej.cire.pl/st,33,335,tr,145,0,0,0,0,0,budowane-i-planowane-elektrownie.html [access: 16 VIII 2017].

[8] *The Programme for the Hard Coal Mining Sector in Poland*, Ministry of Energy, Warszawa 2016, p. 80.

Polish industry specializes in a conventional resources mining. PGNiG S.A. company exploits national resources of gas and crude oil. JSW S.A., PGG sp. z o.o., Bogdanka S.A. is engaged in hard coal mining. PGE GiEK S.A., ZE PAK S.A. and KWB Sieniawa sp. z o.o. deal with the lignite mining. Polish companies are the largest manufacturers of machinery and equipment.

Famur S.A. Group (inter alia Kopex, Famak, Famago, Fugo, Pioma), Bumech S.A. and Fasing S.A. produce all kinds of mining machinery and conveyors. The RAMB company from PGE S.A. group has recently launched the execution of its first comprehensive orders for the benefit of KWB Turów. Research institutes and design offices e.g. Energoprojekt-Katowice S.A., SKW Biuro Projektowo-Techniczne sp. z o.o., Poltegor-Projekt sp. z o.o., Główny Instytut Górnictwa (the Main Institute of Mining), Poltegor-Instytut, Instytut Chemicznej Przeróbki Węgla (the Institute of Chemical Coal Modification) are very active on the market as well. The tycoons of the Polish market together with Polish sub-contractors have capacity for searching and exploring deposits as well as building shafts, mines designing and doing extractions. We have a comprehensive know-how and a production base for machinery and equipment to lead new extraction projects.

Things look slightly different in the case of generation installations caused by a technological underdevelopment of Polish companies in terms of efficiency and carbon footprint. Nevertheless, the construction companies Elektrobudowa S.A., Mostostal Warszawa S.A. and Polimex Mostostal S.A. perform the maintenance of construction contracts and deliver steel structures for power plants and thermal power stations constructed in Poland. The companies Rafako S.A. and Remak S.A. provide boilers and instrumentation for coal power plants and Energoprojekt-Warszawa S.A. and HydroErgia sp. z o.o. for the water power plants. Tens of small and medium-sized companies produce parts and equipment for mining and energy sector. Konsorcjum Przemysłowe INTEC-WAKMET, Grupa Revico, Ania Holding, CHEMAR sp. z o.o. or Fabryka Kotłów SEFAKO S.A. are additionally worth mentioning. There are no Polish producers of steam and gas turbogenerators. We employ the solutions of Siemens, General Electric, Doosan Škoda Power or Mitsubishi Hitachi Power Systems Europe. It seems unreal today that Zamech company from the city of Elbląg will restore its former state-owned structure. After its privatisation in 1990 the ownership of the company changed hands from ABB and Alstom to General Electric. However, the worst situation in the Polish industry can be observed in the renewable resources sector caused mostly by a shortage of companies producing modern and competitive gearless turbines. The situation in the area of solar energy is slightly better – major in the production and utilization of solar collectors (heating water storage tanks). FreeVolt company from the city of Bydgoszcz specialises in photovoltaic panels and it carries out further advanced research on the use of grapheme, which would increase the efficiency of the cells by several dozen percent. The development of the technologies could be stimulated by the industrial policy of the state to be realized by the four biggest state-owned energy groups. As far as the distributed energy and micro-installations are concerned we are just at the start of a long road in spite of its advantages and scattered financing of thousands of small investors.

The availability of technological and production facilities, machinery and equipment for mineral exploration and generation of electricity offers additional advantages for the national economy. It generates technological development of Polish companies, high schools and research institutes and valuable well-paid work places requiring high skills (in case of Polish economy they amount to almost half a million work places).

The development of national industry concerns requires greater attention from the side of public authorities than the start-ups in new technologies sector, especially as the risk of negative verification of the business model in case of start-ups is much higher. Compared to its western counterparts Poland suffers from the shortage of major industry enterprises which translates itself into inability of the Polish technical universities to find a business partner and poor innovation of the overall economy. There is a deficit in terms of experienced companies with cash reserves and creditworthiness ready to take up a challenge of the commercialization of new technologies. This structural weakness of Polish economy is historically m motivated. Polish companies competition with other western entities on an open international market was hampered because of non-market growth conditions in the socialist economy and the consequences of organizational and cultural conditions, for example influences of anti-development groups or inflexible attitude of trade unions. In its difficult past Poland found it harder to be competitive in the open international business market as the obstacles to the market development prevailed in a social economy supported by an overall unwilling organizational and cultural approach displayed by the so called "groups of interests" compounded by an inflexible trade union's stance.

Commercial transactions were limited in the socialist economy for political reasons which instantly affected the insufficient development of companies of high degree product and technology specialization. Different competences were divided amongst different works instead of being concentrated in one entity providing services to those plants. Instead of focusing high skills in competences at one place they would be scattered among different establishments contributing thus to a further inefficiency. Following no top-down centralisation of competencies was carried out. The governments of the so called Third Republic of Poland abandoned a coordinated industry politics, and gave up collecting data on the progress of the companies privatized by the provincial and central authorities.[9]

Western model of capitalism produced companies based on technologies (patents, know-how), skilled employees, knowledge of markets, economic relationships, while the communist bloc exploited solely resources afforded to the by a state, which in turn owned all the existing business undertakings. There was no distinction in the ownership

[9] B. Godusławski, *Prywatyzacyjne fakty i mity. Do dzisiaj nie wiemy, ile firm sprzedaliśmy*, http://biznes.gazetaprawna.pl/artykuly/1087293,prywatyzacyjne-fakty-i-mity.html [access: 25 XI 2017].

of the mining and energy companies (mineral exploration and energy production) and the manufacturing companies (production of machinery and equipment for mining). Though there existed some manifestations of top-down coordination within economic policy in the socialist countries, potent technological companies matching the western standards could not be created.

Their presence on a huge market would require high costs of research and the fixed costs of employing specialists. The challenge of international expansion is not the discretionary management decision but results from the structural need to conduct a specific business activity. The Polish economy undergoing the transformation failed to provide the potential champions with stable conditions sufficient to withstand the strongest turmoil in the market. First of all, because of the dysfunctional model of the political system transformation we were keeping foreign markets away while the domestic market was not sufficiently adequate to accommodate highly specialized companies, devoid of the opportunity to take out loans which would allow them to make a progress in terms of technological development.

The economic failure during the Real Socialism resulted from the central planning policy promoted a far-reaching vertical integration of the industrial plants. Because of the limitation in goods and services available, energy companies created stockpiled in all possible areas (i.e. spur lines, means of transport, component production, refurbishment facilities, catering, hotel facilities, vacation facilities, sports facilities). There were even workplace farms at some bigger companies, aimed at supplying food to cafeterias. In the aftermath of the political changes simple services, like security provision, cleaning, logistics, catering, were handed over to external entities (although sometimes existing still in the holding/within the group). The processes requiring advanced competences and technical background remained within the state energy companies, for example construction works, renovation works, production of components and semi-finished products.

Once deciding on future investments in the production capacity of the subsequent power plants, the Polish government should aim at enhancing their financial condition and technological competences. The analogy to the programme for modernisation of the Polish Military Forces was therefore mentioned before on purpose. With the purchase of weaponry not available in the country, an offset agreement is signed to guarantee a transfer of technologies and involvement of the national companies in the production of components, service and assembly. The energy, oil industry, telecommunication and weaponry are the strategic areas as well, which should be provided with technological and business independence, as the example of South Korea and Taiwan's successful economies prove.

It is a wrongful assumption that the technologies development in the state should be correlated with the development of business organizational structures, which will, in turn, commercialize new products or solutions. The production implementation in Poland is relatively weak and the state-funded implementation of the S&R projects proves to be corporate governance. The political culture of our elites is not particularly favourable towards new economic projects to be initiated by the state and is domineered by the negative experience in the gallium nitride, graphen commercialization or products based on CNG and LNG-based products.

Facing the upcoming energy transformation triggered by the aging power blocks and the changes within the scope of international regulatory environment, we should open the Polish energy balance to technologies that we already possess or technologies that we are able to master in terms of scientific development and production. Undoubtedly, Polish energy mix will still be based to a large extent on hard coal, lignite, natural gas, biomass and water power. The wind power is included in the options and nuclear energy is still under consideration. I think that given the choice between two types of technology of comparable costs (for example wind power plants at sea and nuclear power plants) we should take into account a higher share of polonisation of the financial stream which undeniably works in favour of wind energy. The reduction of the prolonged construction risk, exceeded costs calculations or even the risk of suspending works should convince us that nuclear energy is too complex for us. We have already stopped the construction of a nuclear plant in the town of Żarnowiec once and the work schedule described by the Council of Ministers in a document *The Polish Nuclear Energy Programme* of 28 January 2014 is already overrun. Unfortunately, at present we are following Brazil's footsteps. The country is a model example of the immature energy policy and its nuclear programme looks as follows:

The construction of the first Brazilian nuclear power plant started in 1971 in Angra dos Reis, a town with no manufacturing traditions ca. 130 km from Rio de Janeiro, 220 km from São Paulo and 350 km from Minas Gerais. One of the national energy business concerns was the investor and the American Westinghouse supplied technology. The first block, Angra with a capacity of 657 MW, was finished in 1985 after 14 years: construction and two court trials and numerous shortcomings on both sides. The contract with Westinghouse was a turn-key project without handing over key technologies (including uranium enrichment technology, i.e. fuel production for their own plant) to the Brazil party. Therefore the Brazilians signed a cooperation agreement already in 1975 with German Siemens for constructing subsequent blocks and additionally transferring the technology of nuclear fuel production across the ocean. The construction of the two reactors was launched based on the Siemens technology. Due to the money shortages, the construction was suspended in the years 1986-1995. It was only in 2000, when the construction of Angra II reactor was completed. Following the blackout in 1999 caused by the water plants shut-down caused by a draught, further construction has been accelerated. The construction of third reactor started in 1984 and has been continued since 2009 in cooperation with the French Areva, despite previous announcements that Brazil would achieve total technological autonomy in the whole cycle of uranium extraction and enrichment, power plant construction, power generation and nuclear waste disposal two years earlier. It is worth mentioning that Brazil is endowed with uranium resources, more than 5% of the world's resources, so it is naturally destined to use nuclear energy (unlike Poland).[10] In spite of the ambitious plans from 1960s and periodically confirmed construction of at least three nuclear power plants, the construction of the first one is due to be completed only in a few years time, after the elapse almost 50 years since the implementation project began.

There is no doubt that Brazil is currently technologically much more advanced in nuclear energy than Poland. Nevertheless, the path it had taken (the costs of roughly several billion of the then dollars over 50 years), does not encourage to take up similar challenges by Poland. The acquisition of the nuclear technology from a foreign partner in case of a post-colonial country, with a poor institutional structure, financial markets, unstable political system and non-established political culture will, most probably, be doomed to failure. Such experience for Poland, although on a smaller scale, was the construction of a gas terminal in Świnoujście. Its contractor, Italian Saipem, exceeded investment budget and was overdue with the schedule of putting it into operation. For the last few years, it was the same with most nuclear investments conducted by western companies (Olkiluoto in Finnland, Hinkley Point in the UK, Vogtle in Georgia and Virgil C. Summer w South Carolina). Problems encountered by Slovakia are also worth mentioning. There are already four reactors in the state. It may be concluded that the country has some experience in nuclear technology. The construction of the two additional blocks in Mochovce power plant started in 1998 and it was resumed in 2008 after 10 years. The schedule of works was extended in 2017 for another six-year period, raising estimated expenses for the fourth time, although the costs exceeded twice the base level. Money is frozen for a long time without positive cash flow. This is the risk we should be aware of.

The cost of 1 MW in nuclear power plant has been constantly increasing and in case of the wind power plants at sea it has been constantly decreasing. So, maybe guided by the principle of the country's own energy sources (renewable and fossil) and our own energy production technologies, it would be much quicker to develop a company producing wind turbines than trying to master nuclear energy technology in energy sector. We would avoid the risk of growing costs and deadlines as well as future accidents and problems with radioactive waste disposal. The decision of the German government on the nuclear power abandonment should be a lesson to us not to follow the same path. Two companies executing at the moment their projects of wind farms on the Baltic Sea, i.e. Polenergia 1 200 MW and PGE Energia Odnawialna 1 040 MW had planned their power at the level of two out of the three nuclear power plants planned in the Pomerania Region. In 2017 the construction cost of 1 MW in a nuclear power plant exceeded (in case of the French and American technologies) the cost of the same investment in wind power. The advantages of wind power plants are lower operating costs, shorter construction time, reduced risk of failure and no fuel costs. The disadvantages are the lack of controll ability and the lower installed capacity

[10] *Angra-3 PWR Nuclear, Brazil*, http://www.power-technology.com/projects/angranuclear/ [access: 22 VIII 2017].

utilization rate. Therefore, they require their complementing with a reserve source (preferably gas), which is the cheapest in terms of investment level (CAPEX) and the most expensive in usage (OPEX). Nevertheless, we should remember that nuclear power plants are also inflexible: during night time hours with low energy demand they can reduce their production only by 10% of the installed power. A predominant argument in the decision making process as far as new energy mix for Poland is concerned shall be the possibility to use domestic technologies and the engagement of Polish suppliers of generating installations. Currently, the Polish shipbuilding industry (i.a. Stocznia Remontowa Nauta S.A. and Energomontaż-Północ Gdynia S.A.) provides components for the offshore wind farms. Nevertheless, this involves much lower investment costs compared to those that would be allocated abroad for the nuclear power plant. Maintaining the financial flow for the purposes of the transformation of the Polish energy sector will be decisive factor in the potential promotion to a group of developed countries. Since, the key to development is strengthening mining sector and energy production domestic companies. It is a chance for Polish industrial policy which cannot be overlooked and wasted.

Abstract

Energy security comprises of four factors: independence of energy sources; stability of energy system, electricity lines and pipelines; diversification of both foreign supplies of energy sources and energy mix structure; technology autarky meaning domestic ownership of energy enterprises. This paper is focused on the fourth factor. Author indicates that Poland has well developed industry of hard coal and lignite mining, building coal, wind and hydroelectric power plants. Polish industry's shortage is a lack of domestic producer of steam and wind turbines. Polish companies have the smallest potential in building a nuclear power plant. In case polish government decided to build one it would cause a leakage of billions of zlotys abroad.

Keywords: energy security, energy mix, energy independence, economy, energy sector.