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ENERGY SUPPLY SECURITY OF GERMANY IN THE PROCESS OF ENERGY TRANSITION

Introduction

The provision of energy supply is together with competitiveness and sustained development the overriding purpose of German energy policy. The energy must be supplied in a continuous and undisturbed manner. It concerns not only carriers of primary energy supply (the diversification of suppliers and supply routes is relevant) but also electric energy supply.

Energy supply security can be defined as a accessibility and reliability at beneficial prices. Energy supply security is provided when consumers can cover their demand for energy currently and in the future. It means that energy must be accessible in the predetermined form, time and place, that is there when it is used. Therefore, energy supply security encompasses all levels of the supply chain starting with exploitation and processing of primary energy, through the further processing (in refineries, etc), electric and thermal energy output through transport and distribution to end with trade[2].

The energy transition (*Energiewende*) is a process of Germany's evolution from high-emission forms of economic development to the system basing on exploitation of renewable energy sources in production of electric energy, higher energy efficiency and reduction of its consumption. It is aimed to reduce the dependency on individual energy carriers (nuclear energy, coal) or on energy resources imports (oil, gas, uranium) and in consequence on prices in international energy markets as well as to augment the long-term competitiveness of German

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[2] Kirsten Westphal, „Die Sicherheit der Energieversorgung – Herausforderungen für die deutsche Aussen- und Sicherheitspolitik", in: Stephan Böckenförde, Sven Bernhard Gareis (ed.), *Deutsche Sicherheitspolitik. Herausforderungen, Akteure und Prozesse* (Opladen&Toronto: Verlag Barbara Budrich, 2014), 218.

renewable energy sector[3]. *Energiewende* puts mainly electric energy output in Germany in a position to face a lot of challenges. The rising share of renewable energy sources in the electric energy output causes the electric energy supply reliant on meteorological conditions. Thus balancing of electric energy demand may be provided through the electric energy imports, construction depots or adaptation of short-term demand. Electric energy output from fossil fuels is also not insignificant in this context.

The objective of the study is to present the problem of energy security provision in Germany within the frameworks of currently realized energy transition. The essence and assumptions of energy transition have been taken into account in the article as well as the evaluation of the hitherto progress in the realization of specified aims of the energy transition has been conducted.

Energy transition assumptions

Energy transition bases on three pillars: phaseout of nuclear power plants till 2020, buildup of renewables and activities for saving energy and increasing energy efficiency. However experts notice that the objectives mentioned above, especially the development of renewable energy industry and increase in energy efficiency are present in German policy for a long time as are present the challenges and risks concerning the buildup of energy network, energy sources dependent on meteorological conditions and provision of competitiveness in electric energy supplies[4].

After the Germany's unification energy supply security was to be provided thanks to the diversification of energy sources and supplies as well as the usage of domestic energy carriers. The principal aims of German energy policy in 1990s were, among other things, integration of former Eastern *Bundeslands* with the energy system of the former Federal Republic of Germany, modernization of electric energy delivery, reduction in environmental ballast by the energy consumption, saving energy, rational employment of energy as well as support for the development of renewables. Substantial changes in German energy policy, particularly as regards the objective of energy supplies provision, were initiated together with foundation of the SPD/Alliance '90/The Greens coalition government in autumn of 1998. The emphasis was put on the development of renewables, which was to be provide with the special legal act (*the Renewable Energy Sources Act* from the 29th March 2000 that was multiply amended in the ensuing years), and on resignation from use of nuclear energy till 2022. The Grand Coalition (CDU/CSU/SPD, 2005-2009) continued political agenda of their predecessors retaining in force the decision to renounce exploitation of nuclear power plants and

[3] Beata Molo, „Międzynarodowy kontekst niemieckiej Energiewende*"*, *Rocznik Bezpieczeństwa Międzynarodowego*, 1 (2015): 73.

[4] See: Esther Chrischilles, Hubertus Bardt, „Fünf Jahre nach Fukushima. Eine Zwischenbilanz der Energiewende", *Institut der deutschen Wirtschaft Köln, IW-Report*, 6 (2016).

developing renewables, which was expressed by enacting *the Basic Elements of an Integrated Energy and Climate Program* (*Ecpunkte für ein integriertes Energie- und Klimaprogramm*) in 2007. On the other hand, ruling coalition CDU/CSU/FDP (2009-2013) took a decision in the autumn of 2010 to prolong the period of nuclear power plants exploitation for additional 8 or 14 years, depending on their age, justifying it with important significance of nuclear energy as "the transitional technology" until after 2030 the electricity will be to a bigger degree produced with the use of renewables. Yet the Fukushima-Daiichi disaster in March 2011 brought about a shift in the stance of the federal government toward exploitation of nuclear power plants[5] – a decision to gradually phase them out till 2022 was made.

Energiewende was initiated with the reception by the federal government the conception of energy policy to 2050 (*Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung*)[6] on the 28th September 2010 and next with the passage of package of acts in June 2011, which were aimed at acceleration the strategy implementation in the context of decision to give up nuclear energy exploitation to 2022.

The idea of energy policy conception to 2050 was to base the socio-economic development on the energy mix in which gradually conventional energy sources would be substituted by renewables. The document consists of approximately 60 means indicating manners of carrying out the following objectives:

- the 40% reduction in greenhouse gas emissions to 2020 (the purpose formulated by minister of environment Sigmar Gabriel and subsequently written in *the Basic Elements of an Integrated Energy and Climate Program* from 2007) and the 80% reduction till 2050 in relation to 1990;
- the 80% increase in the share of renewable energy sources in the gross electricity output to 2050, the 50% decrease in primary energy consumption to 2050 relative to 2008 and the 60% growth in the share of renewables in the gross final energy consumption to 2050. The buildup of 26 GW wind power plant at sea to 2030 as well as the buildup of wind energy industry at land, including the replacement of old installations with new more efficient ones, were prioritized;
- the extension of nuclear power plants exploitation for additional 8 or 14 years, depending on their age (what meant that the last nuclear power plant would be deactivated in 2036);
- the enhancement of energy efficiency: the 20% reduction in the primary energy consumption to 2020 and the 50% reduction to 2050 relative to the level from 2008, which demand on average 2.1% annual growth in efficiency as concerns

[5] See: Beata Molo, *Die Energiepolitik Deutschlands im 21. Jahrhundert. Determinanten-Ziele-Massnahmen* (Berlin: OEZ Verlag, 2014); Annika Sohre, *Strategien in der Energie- und Klimapolitik. Bedingungen strategischer Steuerung der Energiewende in Deutschland und Großbritannien* (Wiesbaden: Springer VS, 2014).

[6] „Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung", retrieved 22.08.2016, www.bundesregierung.de.

the final energy consumption. The electricity consumption should be reduced by 10% to 2020 and by 25% to 2050 in comparison with the level from 2008. Modernization of building index ought to be doubled from the current 1% level annually to 2% of total housing resources. By the same token, the demand for thermal energy in buildings should drop by 20% to 2020 and the demand for primal energy should plunge even by 80% to 2050 in relation to 2008. In the transportation sector the reduction in the final energy consumption should reach about 10% to 2020 and about 40% to 2050 relative to the level from 2005.

The remaining relevant assumptions of energy strategy are the following: the buildup of electric power network, especially electric energy transportation on significant distances, the augmentation of depots' efficiency as well as the advancement in research and development works dedicated to new energy technologies[7].

The catastrophe in nuclear power plant in Japan in March 2011 contributed to taking actions – over the short period of time – serving for modification of German energy strategy, including also plan of progressive phaseout of nuclear power plants to 2022[8]. Finally, on the 6th June 2011 the federal government approved so-called Energy Transition Packet (*Energiewendepaket*) and presented basic assumptions of energy transition (*Eckpunktepapier zur Energiewende*), bills and projects of enactments as well as a number of other documents. The detailed resolutions of the energy packet – accepted in summer 2011 are aimed at realization of principal assumptions of federal government's energy concept from 2010.

The concept of energy policy to 2050 was preceded by the mentioned *Basic Elements of an Integrated Energy and Climate Program* from 2007. The document presumed, among other things, the 25-30% increase in share of renewables in the gross electricity production and the 14% increase in thermal energy production to 2020. The growth of biogas share to 10% was, in turn, to contribute to the reduction of German reliance on gas imports[9]. Tasks and directions of actions included in the program were aimed at doing its duties by Germany which had been by it accepted at EU summit in Berlin in March 2007. On the 5th December 2007 the federal government approved the packet of means serving for realization of integrated energy and climate program assumptions accepted in Meseberg. The packet consisted of propositions of changes in the binding legal acts[10]. The first part of the integrated energy and climate program were accepted by the federal

[7] Ibidem.

[8] See: Beata Molo, „Problem zapewnienia bezpieczeństwa energetycznego Niemiec w kontekście stopniowej rezygnacji z użytkowania elektrowni jądrowych*", Przegląd Zachodni*, 2 (2013), 69-89.

[9] „Ecpunkte für ein integriertes Energie- und Klimaprogramm*",* retrieved 22.08.2016, www.bmwi.de.

[10] „Bericht zur Umsetzung der in der Kabinettsklausur am 23./24.08.2007 in Meseberg beschlossenen Ecpunkte für ein Integriertes Energie- und Klimaprogramm", Bundesministerium für Wirtschaft und Technologie, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 05.12.2007, retrieved 24.06.2016, www.bmwi.de.

government on the 18th June 2008. (*Novelle von Energieeinspargesetz und – verordnung, Gesetz zur Beschleunigung des Stromnetzausbaus, Novelle des Mautgesetzes und der Mauthöheverordnung, Verordnung zu Strom- und Gaszählern, Novelle der Heizkostenverordnung, Eckpunkte für die Umstellung der Kfz-Steuer*) and presumed, among other things, the modernization of existing buildings and the implementation of requirements for reduced embodied energy in new buildings, the more common usage of renewables in heat engineering, regulations regarding of biogas with gas transmission networks[11].

Tab. 1. Assumptions of the energy transition to 2050 (in relation to 1990 in %)

	2020	2030	2040	2050
Increase in the share of the renewable energy sources in energy consumption				
Share in the gross final energy consumption	18	30	45	60
Share in the gross electricity consumption	at least 35	at least 50	at least 65	at least 80
Share in the thermal energy consumption	14			
Share in the transportation sector	-			
Reductions in energy consumption and increase in energy efficiency				
Prime energy consumption	-20	-50		
Energy efficiency	2,1/year			
Gross electricity consumption	-10		-25	
Demand for prime energy			-80	
Demand for thermal energy	-20			
Final energy cinsumption	-10		-40	
Reduction of the greenhouse gas emissions				
Greenhouse gas emissions	at least -40	at least -55	at least -70	at least -80 do -95

Source: *Die Energie der Zukunft – Erster Fortschrittsbericht zur Energiewende*, Bundesministerium für Wirtschaft und Energie, Berlin 2014.

Energy supply security in the context of the energy transition process

In the course of energy transition numerous steps and "indirect objectives" are formulated and the progress in realization of the specific assumptions and aims are regularly presented by the federal government in the form of report from monitoring or are an effect of studies of the experts taking up this subject-matter.

[11] „Gabriel: Steigerung der Energieeffizienz hilft dem Klima und den Verbrauchern. Kabinett verabschiedet zweites Klimapaket", 18.06.2008, Pressemitteilung, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, retrieved 24.08.2016, www.bmu.de.

Below some aspects of German energy supply security will be presented in the context of basic assumptions of the energy transition.

The development of the renewable energy sources

The development of the renewable, which is one of the pillars of energy transition, is expected also to contribute to the improvement in the German energy supplies security. The renewable energy sources become increasingly important element of German energy balance. They share in the primary energy consumption have risen systematically since 1990 to reach 12.5% in 2015. The most salient domestic energy carriers were renewables with 40.9% percentage and brown coal with 39.4% share. Within the share structure of the renewable energy sources in the consumption of primary energy biomass is dominant with 56.5% percentage, however the solar energy share is 10% and wind energy share is 19%[12]. Since 1990 a regular growth of the renewables' share in the final energy usage has been noticed. At the same time it began to rise considerably in electric energy consumption after 2010. In 2015 the share of the renewables in the gross final energy consumption amounted to 14.9%, whereas in relation to electric energy it, heating and cooling sector as well as in transportation it came to, respectively, 32.6%, 13.2% and 5.3%[13].

The significant rise of the renewables' share in energy supply in recent years is explained with the employment of various mechanisms for their development, particularly in the electrical power sector. The beginnings of the renewables' development are connected with the Electricity Feed-in Act from the 7th December 1990 (it went into effect on the 1st January 1991), which made enterprises providing the electrical power obligated to taking electrical power generated from water, wind, solar energy, gas from waste yards, putrid gas and biomass. It also assured the guaranteed price for the electrical power produced from the renewables. Moreover, the solar power industry was supported by *1000-Dächer-Programm*.

Act on granting priority to renewable energy sources (also known as *Renewable Energy Sources Act*) from the 19th March 2000 substituted the mentioned Electricity Feed-in Act and extended the range of support including geothermal energy as well. The act stated that the electric power generated from the renewables will be given a priority in the access to the grid and the producer will sell it for the guaranteed feed-in-tariff. Photovoltaics received additional encouragement through the program called *100.000 Dächer-Solarstrom-Programm*. Whereas the act from 2000 included merely the provision of doubling the renewables' share in final energy consumption to 2010, the amended act which came into force on the 1st August 2004 included the purpose of 12.5% increase in

[12] *Energieverbrauch in Deutschland im Jahr 2015*, AGEB 2016, 12, 38.

[13] *Zahlen und Fakten, Energiedaten. Nationale und Internationale Entwicklung*, Bundesministerium für Wirtschaft und Energie, 05.04.2016, retrieved 20.08.2016, www.bmwi.de.

the renewables' share in electric power supply to 2010 and analogous 20% increase to 2020. The amendment from 2004 did not predict restrictions for solar energy, it encompassed the varied system of remunerating for wind installation depending on their power.

The amended act from 2009 for the first time included apart from the provision of the guaranteed feed-in-tariff directly also had a provision of a direct launching the energy generated from the renewables into the market. Due to that provision installations' operators could autonomously sell the electric power produced from the renewables to the third parties.

In turn, the purpose of the amended act from 2012 was to assure sustained development of the energy supply, which diminishes costs and serves for the encouragement of further development of technologies dedicated to electrical power production from the renewable energy sources. Except for the guaranteed feed-in-tariff the amended act had a provision of market bonus for direct marketization of energy generated from the renewables, which was defined as a sell of electrical power produced by either the installations' operators or their distributors on electrical power exchange or on OTC markets. In the process of marketization additional costs for operators emerge which are not incurred by installations' operators benefiting from the guaranteed feed-in-tariff model. Hence the act stipulated the suitable incentive bonus (*Managementprämie*). However, the amended act from the end of June 2012 concerning photovoltaics (*Gesetz zur Änderung des Rahmens für Strom aus solarer Strahlungsenergie und zu weiteren Änderungen im Recht der erneuerbaren Energien*) implemented many changes as regards bonuses for electrical power generated from solar panel installations and determined the upper limit for construction of new photovoltaic installations at 2.5 to 3.5 GW level. Since then the guaranteed tariffs for new photovoltaic installations were reliant on the installed power in the previous period. If the installed power in the previous twelve months totaled between 2.5 and 3.5 GW, tariffs for the new photovoltaic facilities would be reduced by 1% per month. Lower or higher power of new photovoltaic installations was followed by reduction or augmentation of encouragement. In the effect the guaranteed feed-in-tariffs for photovoltaics dropped from about 0.29 €/kWh in 2011 to 0.14 €/kWh in 2014 for small facilities. As well, the installed power in photovoltaics decreased from 7.6 GW in 2012 to 3.3 GW in 2013[14].

On the 8th April 2014 the federal government past the project of the amended the Renewable Energy Sources Act, which aims at halting the growth of energy prices via the reduction in the guaranteed for energy from the renewables, the introduction of annual limits for construction of new facilities producing electrical power form the renewables and, last but not least, the acceleration in integration of the renewables with the energy market. The planned limits for construction of new powers were intended to restrict the construction of new photovoltaic installations

[14] Hans-Wilhelm Schiffer, *Energiemarkt Deutschland. Jahrbuch 2015. Daten und Fakten zu konventionellen und erneuerbaren Energien* (Köln: TÜV Media GmbH, 2014), 315-324.

to gross 2500 MW annually, the onshore wind farms to the 2500 MW annually, biomass power plants to 100 MW annually, offshore wind farms to 6500 MW till 2020 and 15000 till 2030. In the case of photovoltaics, the guaranteed tariff was decreased to €13.15 for facilities below 10 kW and €9.23 for facilities above 10 MW. If the development of wind energy remains in fixed limits the guaranteed tariffs at the level of 8.80 €/kWh will be diminished by 0.4% every quarter. In case the installed power is lower than 2 GW a year the feed-in tariffs will remain at the current levels, whereas in case of growth in installed power above 3.2 GW the degression would deepen from 0.4% to 1.0% quarterly. In case of offshore wind farms the level of support has been determined as 15.40 kWh through the twelve months period. The extension of the encouragement period was stipulated by half month for the thirteenth and every subsequent maritime mile off the shore and, additionally, if the wind farm was installed in the place where the depth is bigger than 20 m and by 1.7 month for every additional meter of depth. The amended act facilitates market integration of new renewable installations through obligatory direct sell on spot market, halting the feed-in tariff system in the periods of negative energy prices and bringing into existence a pilotage phase for auctions encompassing 400 MW free-standing photovoltaic cells. The foreign electric power producers will gradually gain access to the system of encouragement for renewables and since 2017 they may provide 200 MW power a year[15]. The act includes the conditions for giving exemptions and reliefs in fees for electric power for energy-consuming industry. The federal government justified privileges for selected enterprises, in particular aluminum foundries and steel mills, with competition requirements on global markets. On the 8th April 2014 an agreement between the European Commission and the federal government was concluded on this matter. The number of enterprises taking advantage of cheaper electrical power was reduced from 2100 to 1600. According to the new guidelines approximately 350 enterprises had to return to the state treasury €300 mln in tax reliefs which were contrary to the EU law. The amended EEG act was in accordance with new directives of the European Commission on public financial support by member states given to the energy industry and environmental sectors of economy presented on the 9th April 2014[16].

Within energy transition for electric power sector very ambitious objectives have been formulated – an increase of renewables' percentage in gross electric power output should rise to 80% till 2050, however the indirect purposes are as follows: the 35% rise till 2020, the 50% rise till 2030 and the 65% rise till 2040. It means the 15% growth in every decade. The amended EEG act from 2014 implemented extra indirect objectives for years 2025 and 2035 – the 40-45% rise

[15] See: Elina Reschke, *Das Erneuerbare-Energien-Gesetz (EEG) und das europäische Beihilferecht* (Marburg: Tectum Verlag, 2014).

[16] „Komunikat Komisji, Wytyczne w sprawie pomocy państwa na ochronę środowiska i cele związane z energią w latach 2014-2020" (2014/C 200/01), retrieved 20.08.2016, www.wfosgw.poznan.pl.

and 55-60% respectively.

In 2000 the renewable energy sources' share in electrical power sector was about 6.5%. The achievement of the assumed objective of 35% share in 2020 requires 1.43% yearly increase. In 2015 growth reached 21.4%, which complied with the 27.9% renewables' share in the gross electrical power output. Therefore the developmental aim measured by growths from the base year according to the accepted methodology was featured with 117% percentage of the objective's realization. Especially in solar energy field a significant increase of energy was realized between 2010 and 2012 excelling the purpose designated by the federal government. The growth reached in 1.7 GW 2010 and 3.5 GW in 2012. Over this period actually installed power amounted to 7 GW[17].

The renewables' share in the gross electrical power usage in 2015 amounted to 32.5%. Therefore its percentage in electrical power supply in the last year increased by 5%. So it closes to achievement of the federal government's objective to make the renewables covering 40-45% of gross electrical power consumption by 2025. The output electrical power generated form the renewable energy sources increased ten times from 19.7 TWh in 1990 to 194.1 TWh in 2015[18]. Interestingly, relative to 2014 the growth was 31.6 TWh. The wind energy accounted for the largest percentage in this increase, namely +28.7 TWh (onshore 22 TWh and offshore 6.7 TWh) – in total onshore electrical power ouput in 2015 reached 77.9 TWh, whereas offshore electrical power output reached 8.1 TWh. The production of electrical energy from photovoltaics totaled 38.5 TWh in 2015 (growth by 2.4 TWh towards 2014), from biomass – 49.9 TWh and from water energy remained at the same level as in 2014 – that is 19.5 TWh[19]. In 2014 the installed power of new onshore wind energy farms equaled 4.4 GW in contrast to 1.4 GW of offshore wind energy farms electrical power production. In the first three quarters of 2015 the added power of onshore wind energy facilities reached 2.5 GW, whereas the offshore wind energy facilities connected to the electrical grid equaled 2.35 GW[20].

According to the study prepared by the advisory bureau ERA ordered by the Greens faction in the Bundestag the build-up of onshore wind energy industry is going to collapse. In order to realize the objective of 45% share of the renewables in electric power consumption by 2025 one should install 1500 MW of power every year. Yet it is insufficient to exchange the older wind farms for modern ones to 2025. It means that production efficiency shrinks. Thus it is going to lead to the stagnation in electrical power output generated from onshore wind energy facilities the in the 2020s[21].

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[17] Chrischilles, Bardt, *Fűnf Jahre,* 9-10.

[18] *Energieverbrauch in,* 28.

[19] Ibidem.

[20] Thomas Vahlenkamp et al., „Energiewende-Index Deutschland 2020 – Kraftakt Atomausstieg", *Energiewirtschaftliche Tagesfragen,* 3 (2016), 27.

[21] *Auswirkungen des Referentenentwurfs des EEG 2016 auf das Ausschreibungsvolumen der Windenergie an Land*, ERA, April 2016, Berlin, retrieved 20.07.2016, www.gruene-bundestag.de.

The development of the renewable energy sources puts the German energy supply security ahead of many miscellaneous challenges, amongst them one could, among other things, include:

- the necessity to assure the buildup of the renewables at the possibly constrained costs. For there is conflict between, on the one hand, the quick development of the renewable energy sources and, on the other hand, affordable electrical power supply.
- creation of specific conditions for the renewables' development , especially the integration of the renewable energy sources in the transmission grid and in the electricity market. It also concerns the construction of high voltage electricity grids, which transmit electric power from the north to the south of Germany as well as the local distribution networks.
- technical difficulties, which may appear more often together with the development of instable electrical power sources. The equalization of the electricity supply can be accomplished not only through the development of transmission grids but also due to the buildup of warehouses. Otherwise, electricity imports and construction of conventional power plants will be essential[22].

Cost-effectiveness (profitability)

One of the most serious difficulties in the development of the renewable energy sources are their costs. The costs are often connected with so-called EEG-surcharges (*EEG-Umlage*) – the final recipients incur them in the form of higher electricity bills. The largest share in subsidizing of the energy sector falls directly to individual energy consumers and those enterprises which are not exempted from financing of the renewable energy development. Recipients representing energy-intensive branches of the industry (mainly producers of steel, aluminum, cement) are either entirely or partially exempted from the EEG-surcharges, which is to serve to keep their competitiveness on global markets. EEG-surcharge resulted in the 20% rise in electricity prices relative to the base prices. The biggest increase appeared ensued over the years 2010-2013 due to rapid growth in costs of photovoltaic facilities. In 2015 the EEG-surcharge totaled 6.17 cents per kWh. That means that the renewables' development is not accompanied by the enhancement of cost-effectiveness (profitability). In 2015 the support for the renewables amounted to €21.5 billion – for the first time ever its drop was noticed (from the €22.4 billion in 2014)[23].

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[22] Esther Chrischilles, Hubertus Bardt, *Energiewende-Radar, Fortschritte beim Umbau der Stromversorgung in Deutschland von 2000 bis 2012*, Gutachten für die Initiative Neue Soziale Marktwirtschaft, Köln, 13 September, 2012, 9-10.

[23] See: Bundesministerium für Wirtschaft und Energie, www.bmwi.de.

Security of supplies

Within the energy transition electricity output is to be based to a large extent on the renewable energy sources. The increasing share of the renewables in electricity production leads to supply which is dependent, in substantial part, on meteorological fluctuations. Therefore the need of stabilization in demand for electricity generated from renewable emerges. That is why in the process of the energy transition conventional power plants have a salient significance since they can substitute installations from instable renewable energy sources.

For the German energy supply security a particular significance is put to the development of the power plants' stock. By the 2019 blocs having 4186 MW power will be phased out, whereas the power of power plants currently in construction to 2019 equals 5110 MW, including: 2591 MW of coal fueled power plants, 1954 MW of gas fueled power plants and pumped storage plants in Luxembourg and Austria, from where electric power will be transmitted to German power grid[24].

The is electric energy system in Germany is evaluated as a reliable. According to experts, in the nearest years Germany are not endangered by shortages in electricity supply. Unplanned power deficiencies remain at the very low levels, a sufficient generation adequacy is provided, which means that there are accessible resources to meet the needs at every time. In 2010 electricity interruptions per consumer averaged 14.9 minutes and in 2014 – 12,28 minutes, which mean that reliability of electric energy supplies was at the 99.998% level (excluding shorter breakdowns and interruptions below three minutes). Number of hours in which grids' operators had to implement means serving for evasion of redispatches rose from 1588 in 2010 to 15811 in 2015. This growth was caused by shut-down of the power plant in Grafenrheinfeld, a high increase of energy derived from windfarms, a belated implementation of means aimed at buildup of power grids as well as partial shutdown of elements of transmission infrastructure and a high exports of electricity[25]. The costs of these actions amounted to about €187 mln in 2014 and about €402 mln in 2015 (for comparison €48 mln in 2010). As well, electric power production generated from the renewable is increasingly often regulated in order to assure the system's stability – the costs of such activities equals €82.7 mln on average[26]. In 2015 outage in the work of installations from the renewables and conventional power plants totaled approximately 4722 GWh (2014: approximately 1581 GWh) overall, whereas the total amount of claims for compensation for installations' operators equaled €478 mln[27].

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[24] *Monitoringsbericht 2015. Monitoringbericht gemäß § 63 Abs. 3 i. V. m. § 35 EnWG und § 48 Abs. 3 i. V. m. § 53 Abs. 3 GWB*, Bundesnetzagentur, *Bundeskartellamt,* Stand: 10. November 2015, Korrektur: 21. März 2016, Bonn, 24.

[25] *3. Quartalsbericht 2015 zu Netz- und Systemsicherheitsmaßnahmen Viertes Quartal 2015 sowie Gesamtjahresbetrachtung 2015*, Bundesnetzagentur, 2. August 2016, 9.

[26] Chrischilles, Bardt, *Fünf Jahre,* 20-21.

[27] *Monitoringsbericht 2015,* 24.

The buildup of transmission grids

Formed in the process of energy transition electricity production structure requires a reconstruction and reorganization of all the energy infrastructure. One of the biggest challenges is a question of specific requirements as concerns the transmission and distribution of electric power. The development of the renewables implicates the necessity of transmission infrastructure's adaptation in the context of the following problems:

- the spatial division of production and consumption: the electricity generated on the Gemany's north must be transmitted to recipients in the south, where nuclear power plants will be phased out;
- the rise in number of local facilities having lower power capacities: the electricity produced from the renewables is more frequently transmitted to distribution network than the electricity generated in conventional power plants;
- fluctuations in electricity's quantities derived from the renewables: in contrast to conventional power plants the accessibility of the renewable energy sources is reliant on season, which have bearing on the process of electricity generation.

Among principal challenges regarding the realization of key energy concept's assumptions from 2010 are the lack of progress in the buildup of infrastructure allowing to transmit wind energy from the north to the south of Germany. The crucial investments in electrical power grids running from the Germany's north to the Bavaria are blocked by the CSU which governs this Bundesland. Instead of the electricity from the Germany's north the rise in energy production from local sources, mainly solar energy and biomass, is proposed. Not without significance for the progress in the development of the electrical power infrastructure are the legal troubles concerning the process of expropriations to build the network as well as protests if inhabitants of land through which they are to run.

By the 30th June 2015 amongst 1876 km of new electricity transmission routes (*Energieleitungsausbaugesetz,* EnLAG) 487 km were actually realized, that is approximately one fourth. In the transmission grid operators' assessment possibly by 2016 merely 40% of planned transmission grids will be realized[28]. It is estimated that by the end of 2017 the next 20% will be finished. The total length of all links according to EnLAG act currently amounts to 1816 km (it encompasses 22 projects, two were canceled), but 35% have been finished yet and the further 55% of planned grids will be finished by the end of 2017. In the fourth quarter of 2015 about 56 km was realized (that is 614 km overall)[29].

[28] *EnLAG-Monitoring. Stand des Ausbaus nach dem Energieleitungsausbaugesetz (EnLAG) zum vierten Quartal 2015*, Bundesnetzagentur, retrieved 20.07.2016, www.netzausbau.de.

[29] See: www.netzausbau.de.

The reduction of greenhouse gas emissions

Greenhouse gas emissions in 2015 reached 925 mln of CO_2 equivalent, that is 5 mln more than in 2014[30]. Thus the emission diminished by 26% relative to 1990. The federal government's goal is to restrict the emission by 40% to 2020 (that is by 739 mln tons) and by 80% to 2050. In order to achieve this aim absolutely crucial are suitable energy supply and consumption. Not without significance for the reduction of greenhouse gas emissions is an abandonment of nuclear energy as a non-emissioning energy source. Nuclear power plants having together 12 GW power are going to be phased out by 2022. Concurrently CO_2 must be considerably reduced in order to reach the goal of reduction of greenhouse gas emissions.

In the process of achieve the above mentioned goal a crucial role is ascribed to energy sector. Coal power plants are responsible for 85% of the total emission of the electric power sector. Above half of coal power plants' power is older than 35 years[31]. Currently, there are over 60 lignite blocs having together about 20 GW power in Germany, which are concentrated in Rhenish mining area (approximately 10 GW), Lausitz mining area (approximately 7 GW), in central Germany and in Helmstedt (about 3 GW). For comparison, in 1990 electric power sector emitted 366 mln tons of carbon dioxide, whereas in 2014 (313 mln tons) only 5.8% less greenhouse gas emissions than in 2000 (326.8 mln tons)[32]. In order to meet the assumed goal of reduction to 2020 the greenhouse gas emissions by electric power sector ought to be limited to 219 mln tons.

Despite of clearly rising electrical power output generated from the renewables no substantial reduction in emission by the electrical power industry is noticed. It is caused by significant share of hard and brown coal in the total production of electric power. The aggregated electric power output from brown coal brought about over 150 mln tons of carbon dioxide equivalent emission, whereas from hard coal almost 100 mln carbon dioxide equivalent emission. In order to realize the reduction aim in Germany to 2020, the emissions must be limited by 500 mln tons annually in relation to the level from 1990 (by 40%). By 2015 this reduction totaled 325 mln tons. By 2020 additional 175 mln tons of CO_2 equivalent have to be lowered. It is not possible without simultaneous considerable reduction of greenhouse gas emissions in all energetically important areas: electric power production, thermal power production and transportation[33].

The federal government passed on the 3rd December 2014 *Climate Protection Program to 2020* (*Aktionsprogramm Klimaschutz 2020*). The document consists of the list of actions which are intended to lead to the reduction from 62 to 78 mln of

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[30] *Energieverbrauch in....*

[31] Felix Reitz et al., "Verminderte Kohleverstromung kőnnte zeitnah einen relevanten Beitrag zum deutschen Klimaschutzziel leisten*"*, *DIW-Wochenbericht*, 47 (2014), 1219-1229.

[32] *Zahlen und Fakten....*

[33] *Die Energiewende im Stromsektor: Stand der Dinge 2015. Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2016*, Agora Energiwende, Januar 2016, 31, retrieved 19.08.2016, www.agora-energiewende.de.

CO_2 equivalent in the nearest five years. Due to these activities the goal of reduction in emission by 40% to 2020 should be accomplished. In addition to that, the document consists of the list of "soft" instruments that are to be favorable for reduction in emission through education, consulting and training[34].

The reform of the conventional power plants sector is essential in the context of accomplishment of reduction in carbon dioxide emission by 40% to 2020 by Germany. The essence of the reform should be the complete elimination of the oldest coal power plant from the market and decrease of electric power export. *The Political Agreement between SPD, CDU and CSU on the Future of energy Transition*[35] released on the 2nd July 2015 assumes that power plants fuelled with brown coal having in sum 2.7 GW power (that is 13% of all brown coal power plants' power) will be moved to so-called reserve power and after four years phased out. It means that the power plants will be turned on only on exceptional occasions when the remaining on market power plants will not be able to cover the demand for energy. The coal power plants moved to reserve will be receiving the compensate for four years for the readiness to resume the output. After passing of this time they will be shut down. The new proposition of the ministry will result in lesser reduction in carbon dioxide emission by 22 mln tons to 2020. The lacking reduction will be complemented through the improvement in saving the energy as well as the construction of new thermal-electric power stations.
It is estimated that non-implementation of additional means 2020 will result in over 50% share of lignite in the greenhouse gas emissions by the electricity production sector (28% hard coal, 21% other energy sources). The increasing exports in electricity generated from lignite will lead not only to the growth in carbon dioxide emission in Germany, but also to driving friendly for climate gas power plants from the markets in the neighbouring states.

Energy efficiency

Since the initiation of energy transition the energy efficiency rises on average by 1.5% annually (and is 27.6% below the assumed objective). The efficiency of primary energy carriers enhanced on average by 1.7% yearly between 1990 and 2013. Nonetheless, in recent years the improvement in efficiency slowed down. The efficiency of primary energy rose on average by 2.2% a year between 1990 and 2000, by 1.6% between 2000 and 2015, whereas by 1.9% in the period 1990-2015[36].

In 2010 Germany determined the national objective of reduction in primary energy usage to 2020 by 20% in relation to the level from 2008 (276.6 mln tons of

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[34] *Aktionsprogramm Klimachutz 2020*. Kabinettbeschluss vom 3. Dezember 2014, retrieved 10.07.2016, www.bmub.bund.de.

[35] *Eckpunkte für eine erfolgreiche Umsetzung der Energiewende. Politische Vereinbarungen der Parteivorsitzenden von CDU, CSU und SPD vom 1. Juli 2015,* retrieved 15.07.2016, www.bmwi.de.

[36] J. Blazejczak, D. Edler, W.P. Schill, "Steigerung der Energieeffizienz: ein Muss für die Energiewende, ein Wachstumsimpuls für die Wirtschaft", *DIW Wochenbericht*,4 (2014), 47-60; *Energieverbrauch in Deutschland,* 8.

oil equivalent in primary energy consumption; 194.3 mln tons of oil equivalent in final energy consumption) and by half to 2050. Too, the electrical power usage should diminish by 25% to 2050. In 2015 the primary energy consumption equaled 13.307 PJ (that is 454 mln SKE) and, for comparison, in 1990 it was 14.905 PJ, in 2000 it was 14,402 PJ and in 2008 – 14,380 PJ. In the case of final energy the consumption amounted to 8648 in 2014, whereas in 1990, 2000 and 2008 it totalled, respectively – 9472 PJ, 9235 PJ and 9159 PJ[37]. In order to achieve the assumed aims in the area of diminishment of primary energy and electric power consumption energy efficiency – according to the energy policy conception from 2010 – ought to by 2.1% annually (this objective regards the final energy usage). If observed over the years 2005-2013 trend in primary and final energy consumptions continues, Germany would not manage to realize this purpose. In energy policy conception the objective to reduce electricity usage by 10% to 2020 relative to the level from 2008 was determined, that is the electricity consumption should accomplish the level of 556 TWh in 2020. The pundits assess that the objective of the long-term 25% reduction by 2050 may not be achieved if additional means are not implemented.

Is worth mentioning that the amended Enerhy Saving Act (*Gesetz zur Einsparung von Energie in Gebäuden – Energieeinsparungsgesetz, EnEG*) from July 2013 sharpened existing high standards concerning energy efficiency in building industry. Among other things, the requirement for building the energy-neutral homes since 2020 at the latest was enforced. However, one of the instruments serving for accomplishment of the 14% reduction in the renewables' share in heating and cooling sector by the year 2020 was, amended in December 2011, the Renewable Energies Heat Act (*Gesetz zur Förderung Erneuerbarer Energien im Wärmebereich – Erneuerbare-Energien-Wärmegesetz,* EEWärmeG). In 2014 the renewables' share in the heating and cooling sector amounted to 12%,whereas in 2020 it may reach 16%. The act made obligatory an exploitation of energy from the renewable energy sources in newly built or renovated buildings. If investor decided to exploit the solar energy, it must have cover at least 15% of demand of the specific building for heat and cold, whereas at least 50% in the case of using the biomass. However the National Action Plan on Energy Efficiency (*Nationaler Aktionsplan Energieeffizienz,* NAPE) was enacted on the 3rd December 2014. The strategic purposes included in it assume the enforcement of instruments supporting thermomodernization of buildings and energy saving[38].

Electricity consumption

The energy transition is going to, first and foremost, transform the structure of electricity production. The federal government best not only on shifts in electric

[37] *Zahlen und Fakten...*

[38] *Ein Gutes Stück Arbeit. Mehr aus Energie machen. Nationaler Aktionsplan Energieeffizienz*, Bundesministerium für Wirtschaft und Energie, Dezember 2014, retrieved 10.07.2016, www.bmwi.de.

power output, but also on changes in electricity usage. The diminution of demand for energy is one of basic assumptions of the energy policy conception. It should contribute to both improvement in energy supply security of Germany and play a key role in case of unpredictable occurrences in the process of redevelopment electricity production structure. The goal is to lower electricity consumption by 10% to 2020 and by 25% to 2008.

594 TWh of electric power was consumed in Germany in 2015 (which was 0.8% more relative to 2014). The decreasing electricity consumption trend is being continued as a result of rising energy efficiency. In 2015 the electricity usage was smaller by 21.2 TWh than in 2008 that is a base year for the objective of energy efficiency assumed in the energy policy conception[39]. In order to accomplish the goal of electricity consumption diminution by 10% to 2020 in relation to 2008, its is necessary to faster introduce into the market the energy efficient devices. The electric power consumption during the period 2008-2015 diminished by 3 TWh yearly, that is why the drop in 2015 reached 3.4% value. Nevertheless, this drop is insufficient to accomplish the goal of 10% reduction in electricity consumption by 2020 in relation to 2008. In the next five years it is essential to limit the electricity usage by approximately 8 TWh annually so that electricity consumption in 2020 would be 62 TWh lower than in 2008[40].

Conclusions

The assessment of the hitherto conducted realization of assumption of the energy transition ought to be consistent with the triangle of energy policy purposes, that is, security of supply, competitiveness and sustainability. A particularly germane issue in the context of competitiveness, treated as one premises for the success of energy transition, are their high costs, including prices for electric power. In the latest decade an average price for kWh of electricity grew by 50%. High energy costs can have various social and economic effects, including inhibition of industrial production growth in Germany.

The development of the renewable energy sources advances faster than planned, and as a consequence, results in specific challenges for the security of supply, especially for assuring stability of the transmission system. Hence, instruments aimed at giving an assurance of the security of supply must be compatible with the energy transition's objectives.

Undoubtedly, for provision of security of supply in the medium to long-term perspective, a question of utilization of the surplus in electricity output generated from the renewables will be a challenge. Three solutions to this problem seem to be possible: transmission for longer distances locally generated electricity, storing or processing of electric power into other applied forms. Every of the above mentioned options may result in specific technical difficulties as well as influence

[39] *Energieverbrauch in Deutschland...; Zahlen und Fakten...*

[40] See: Chrischilles, Bardt, *Fünf Jahre.*

in the rise in energy transition's costs.

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Abstract

The article concentrates on the problem of the providing of the German energy supply security in the process of the energy transition. The article presents the beginning and the assumptions of the energy transition, which essence boils down to the buildup of the renewable energy sources as well as activities aimed at saving of energy and the energy

efficiency's improvement. The article also includes the evaluation of the hitherto progress in the realization of the specific assumptions and goals of the energy transition taking into account the aspects relevant for energy supply security provision such as: the renewables' development, supply security, buidldup of transmission networks, reduction in greenhouse gas emissions, energy efficiency and electricity consumption.

Bezpieczeństwo zaopatrzenia energetycznego Niemiec w procesie transformacji energetycznej

Artykuł koncentruje się na problemie zapewnienia bezpieczeństwa zaopatrzenia energetycznego Niemiec w procesie transformacji energetycznej. W artykule przedstawiono genezę i założenia transformacji energetycznej, której istota sprowadza się do rozbudowy odnawialnych źródeł energii oraz działań na rzecz oszczędzania energii i zwiększenia efektywności energetycznej. Artykuł zawiera również ocenę dotychczasowych postępów w realizacji określonych założeń i celów transformacji energetycznej z uwzględnieniem aspektów istotnych z perspektywy zapewniania bezpieczeństwa zaopatrzenia energetycznego takich, jak rozwój odnawialnych źródeł energii, bezpieczeństwo dostaw, rozbudowa sieci przesyłowych, redukcja emisji gazów cieplarnianych, efektywność energetyczna i zużycie energii elektrycznej.

Key words
Germany, renewable energy sources, energy supply security, energy transition

Słowa kluczowe
Niemcy, odnawialne źródła energii, bezpieczeństwo zaopatrzenia energetycznego, transformacja energetyczna

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