

The role of energy policy in agricultural biogas energy production in Visegrad countries

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Abstract. Energy production by agricultural biogas plants has recently recorded considerable growth in Visegrad countries. The development was enhanced by European Union's efforts to increase the proportion of energy produced from renewable sources. The paper aims to assess the role of energy policy in the development of agricultural biogas energy production in Visegrad region. Conducted studies have shown that among various forms of support for energy production from renewable energy sources, the price system prevails, including the support by feed in tariffs and bonuses. Feed in tariffs were adopted in Czech Republic, Hungary and Slovakia. Another kind of support system – a quota system – was adopted in Poland, what includes tendering and certificate systems. The results confirm the adoption of legal framework was necessary step to enable agricultural biogas energy production in Visegrad countries, but itself it was not enough to stimulate development of agricultural biogas energy production significantly. Rapid development in each country was recorded only after the certain financial support systems took effect, what made production of agricultural biogas energy economically efficient for investors. The production of energy from agricultural biogas grew the most in the Czech Republic and Slovakia, where the financial support was the highest. Nevertheless, the protracted process of changes in legal framework and transformation of energy policy, certain measures including state-controlled price-making systems, risk regarding with auction system might hamper agricultural biogas energy production further development.

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1. Introduction

Dynamic population growth and socio-economic development observed since over past decades have increased human pressure on natural environment. As a result of changes which are taking place the society has to bear increasing environmental costs. Therefore, the care for natural environment has become important determinant of further socio-economic development. The two phenomena significantly facilitating that care are technological advancements and the dissemination of innovation because it is the use of state-of-the-art solutions that enables socio-economic development which serves to meet the needs of local communities without causing environmental degradation (Wójtowicz, 2010).

As the production and distribution of energy are the driving force of the economy of each state and region, the energy sector is one of the first to experience transformations related to the pro-environmental approach to economic development (European Commission, 2015). In the light of the current policy of the European Union where one of the horizontal principles deals with sustainable development, it is necessary to initiate actions aiming to protect the environment, in particular in key economic sectors including energy production. Ecological energy projects are implemented utilizing locally available renewable energy sources (RES). The need of innovative actions in the energy sector, manifested in its transition and decentralisation and above all the dissemination of RES, is particularly visible in the post-communist Central European Countries (CECs), including Viseg-

rad countries. On the one hand they are dominated by obsolete power plants and national energy grids, and on the other there is a systematic increase in demand for energy driven by socio-economic development (Kats, 1991; Buzar, 2007; Woodman, Baker, 2008; Boie et al., 2014).

Transformation of energy sector in favour of RES utilization is an opportunity to focus on sources which besides the energy sector stimulate development of another economic activities (Chodkowska-Miszczuk, 2015; Chodkowska-Miszczuk et al., 2016). Energy production from agricultural biogas meets this condition because this kind of biogas is obtained in the process of methane fermentation of organic substrates originating from the agri-food sector, including energy crops and agricultural production waste (Bożym, et al., 2015; Martinát, et al., 2016). Since majority of substrates for agricultural biogas production originates from agricultural activities, establishment of ABPs provides an opportunity for multifunctional agriculture development. The development of ABPs is reflected in changes occurring in agriculture. New functions have appeared and energy agriculture has been more and more common. Agriculture has access to new production fields, and becomes the basis for actions directly associated with the energy security of the country (Chodkowska-Miszczuk et al., 2015).

Such diversification of agricultural activities also helps to keep or even increase employment in rural areas. According to the study by Sidorczyk-Pietraszko (2015), among all installations using RES in Poland, agricultural biogas plants offer the most workplaces per 1 MW of installed capacity – 1.85 person on average. It is almost twice as

much as the second-ranked hydro power plants which generate employment at 0.98 person/MW. ABPs also produce energy in cogeneration, besides electricity a heat is produced what can be beneficial for infrastructure and local socio-economic development.

The focus of this study on agricultural biogas energy production is fostered also by the fact that production of this form of renewable energy is considered as the least affectable by fluctuations (expectable or unforeseeable) of natural conditions what makes agricultural biogas one of the most prospective among the RES. The formation and operation of agricultural biogas plants is to a large extent the resultant of socio-cultural and economic premise characterizing investors, suppliers of substrates used for the production of biogas, as well as inhabitants of rural areas, with which agricultural biogas plants are strictly associated (Wirth et al., 2013).

A lot of research has been dedicated to the agricultural biogas investments. Many papers present the analyses of the production of agricultural biogas plants, their installed power capacity, institutional conditions, as well as endogenous and exogenous factors determining the establishment of agricultural biogas plants including structure of substrates for biogas production or funds for investment (e.g., Weiland, 2003; Lantz et al., 2007; Masár and Božík, 2009; Budzianowski, 2012; Chodkowska-Miszczuk and Szymańska, 2013; Kiedrowicz et al., 2013; Martínát et al., 2013). Other frequently discussed issue is associated with the social and economic factors affecting the implementation of biogas projects, the selection of technology, the size of ABPs, etc. (e.g., Lantz et al. 2007, Han et al. 2008, Raven and Geels 2010, Reise et al. 2012, Emmann et al. 2013, Wirth et al. 2013). Generally, majority of these research papers originate from highly developed Western European countries where agricultural biogas has already strong position in the energy market (e.g., Austria, Germany, Sweden) or from developing countries in South-eastern Asia. However, these issues are still not fully resolved in the post-communist CECs, including Visegrad Group.

The Visegrad Group (also referred to as Visegrad countries, Visegrad four or simply V4) consisting of the Czech Republic, Poland, Slovakia and Hungary was formed after the break-up of former Eastern Bloc to enhance cooperation in various fields in-

cluding cultural, educational, economic issues, foreign affairs, etc. (Visegrad Group, 2016). This region is strongly affected by specific historic and economic circumstances unprecedented in other parts of the world. They were manifested in (1) the domination of one energy source (hard coal in Poland and Czech Republic, nuclear energy in Slovakia and Hungary), high energy intensity of national economies, centralization of the national energy markets, and energy dependence from Russia (Kats 1991, Buzar 2007, Lofstedt 2008), what largely persist even nowadays. (2) Agriculture in these countries was shaped under socialist regime. During this period, after confiscation and nationalization of small private farms, large-scale and state owned farms were created, which persisted till the early 1990s. (3) The end of the previous century brought very important changes in agriculture related to the transformation of the post-communist CECs from the centrally planned economy to the market economy (Bański, 2008). (4) Last but not least, integration of V4 countries into EU is related with adoption of EU policies and targets, including ambition to make energy sector more green and decentralized, and even fully decarbonised by 2050 (cf. Klose et al., 2010; Ruester et al., 2013). These fundamental changes are accompanied by greater market volatility, which increased competitive pressure on farmers. However, there is a substantial potential for improvement of the agriculture and an opportunities to adopt new practices and strategies (Giannakis and Bruggeman, 2015). One of them is the agricultural production for energy purposes, including agricultural biogas production, and energy from biogas.

In the context of mentioned-above, the development of the role of energy policy in agricultural biogas energy production in Visegrad region is addressed in this paper. Following research questions are examined: (1) When and what way the legal framework on promotion of energy production from RES and particularly agricultural biogas was adopted in V4 countries and what measures were employed in these countries? (2) How the adoption of energy policies in V4 countries affected agricultural biogas production development? And (3) what trajectories of development of agricultural biogas energy production are indicated by the current legal framework?

2. Materials and research methods

Quality and quantity methods were employed within the research. In the first step, existing formal materials, mainly strategy documents and national law acts on the energy production from RES and particularly agricultural biogas in V4 countries were analysed. Based on analysis results, the main legal and financial instruments determining the development of production of energy from agricultural biogas development in the each V4 countries were identified.

Despite the EU's regulations on energy production from RES are applicable to all EU member states, there is no authority collecting and providing comprehensive and comparable data on agricultural biogas energy production across individual EU countries. Therefore, statistical data and corresponding methodological and general information were obtained from following authorities: Agricultural Market Agency in Poland (AMA), Energy Regulatory Office in Poland (ERO), the Local Data Bank from the Central Statistical Office in Poland (LDB CSO), the official European Funds Portal (EFP), Statistical Office of the Slovak Republic (SOSR), Regulatory Office for Network Industries in Slovakia (RONI) and Eurostat. Information on development and current state of agricultural biogas use in Hungary was drawn from studies by Fazekas et al. (2013) and Tihányi et al. (2012), and in Czech Republic by Martinát et al. (2013), Martinát et al. (2013a), Martinát et al. (2013b) and data by Czech biogas association (CzBA 2016). Data acquisition was followed by their harmonization, and subsequent aggregation and interpretation. This was complemented by graphic presentation employing map and charts.

3. Research results

3.1. Legal framework for the support of agricultural biogas energy production in the V4 countries

The EU is taking steps to build the Energy Union. In 2015, the Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate

Change Policy was presented (COM/2015/080). The ambition of the strategy is to direct EU to become a common energy system in an efficient manner using locally available, renewable energy resources and intensively developing low-emission technologies. Moreover, EU energy policies aim to regulate a proportion of energy produced from RES in each member country by appropriate documents among which the fundamental one is the Directive of the European Parliament and the Council no. 2009/28/WE. The directive was implemented by EU member countries, including the CECs. Concerning desired proportion of energy from RES in the final energy consumption in EU until 2020 (known as the 20-20-20 targets), the Directive determines mandatory national goal for each EU country. Among the CECs, the highest proportion is supposed to be reached in Poland (15%) followed by Slovakia (14%), Czech Republic and Hungary (both 13%).

Despite clear benefits of energy production from RES its implementation meets many obstacles in V4 countries. Investors have to tackle with prices of technologies that are imported mainly from Western Europe, fluctuations of energy prices, etc. With the aim to eliminate impact of these obstacles, certain support systems are applied in each country. Among various forms of support for energy production from RES, the price system prevails, including the support by feed in tariffs and bonuses. Feed in tariffs were adopted by 21 of EU members including Czech Republic, Hungary and Slovakia by 2014 (RONI 2014). Another kind of support system where the government or competent authority sets annually the amount or proportion of energy to be produced from RES and then allows producer to compete by price offers. This is generally labelled as a quota system and it includes tendering and certificate systems (cf. Soliński, 2008). The certificate system is implemented *inter alia* in: UK, Italy, Austria, Sweden, Romania and Poland. The tendering or auctioning systems are applied *inter alia* in: France, Ireland, Italy (Communication, SWD/2013/439), and according to the Act on Renewable Energy Sources adopted in 2015 (Act No. 478/2015 Coll.) also in Poland from January, 2017.

The Czech Republic, it was first country from the V4 countries to adopt the legal framework on renewable energy. Two important acts (Act No. 458/2000 Coll., Act No. 406/2000 Coll.) were adopted already

in 2000 to regulate state and business conditions in electro energetics, gas industry and heating industry, ensure that the producers of electricity from renewable sources shall be preferentially connected to the transmission system and to regulate effective and considerate consumption of energy and energy sources (cf. Martinát et al., 2013a). This was followed by Act on the Promotion of Use of Renewable Sources (Act No. 180/2005 Coll.) adopted in 2005. In accordance with that law, plants producing energy from RES (meeting requirements given by energy law) must be given priority in connecting to the transmission grid. The act also concerns the feed in tariffs for energy from RES which are updated by Energy Regulatory Office (ERO) annually. This way certain profit for agricultural biogas energy producers became provided. The feed in tariffs in 2014 were ranging from 0.1106 to 0.1499 EUR/kWh (Tab. 1) according to RONI (2014). The goal of National Action Plan for RES adopted in 2010 is to produce 13.5% of energy from RES by 2020. Current strategy for support of energy production from RES is determined by Act No. 165/2012 Coll. on supported energy sources. By this law, the support by guaranteed purchase prices was (temporarily) discontinued for new ABPs.

Next country where the law on RES energy production was adopted is Slovakia. Law on energetics (Act. No. 656/2004 Coll.), similarly with acts adopted in the Czech Republic in 2000, provides general framework and rules of energy market. Law on the promotion of RES (Act No. 309/2009 Coll.), and National Action Plan for RES (NAP for RES 2010) adopted in 2009 and 2010 respectively specify the feed in tariffs policy and determine the rules for the redemption prices creation and regulation. The feed in tariffs are annually issued by Price decision of Regulatory office (RONI) what brings operators and potential investors into uncertainty in profitability and return of investments. In Slovakia, the feed in tariffs for energy produced from biogas decreased from 0.1327 – 0.1467 EUR/kWh in 2010 to 0.1072 – 0.1252 EUR/kWh in 2014 (RONI 2014).

In Hungary, the Act on Electric Energy was adopted in 2007 (Act No. LXXXVI/2007 Coll.). It ensures priority grid connection to electricity generated from renewable energy sources. However, only further legislation adopted in 2008 determined the policies on sales and feed in tariffs to

provide some guarantees for green energy producers. Further government regulation on regulation of redemption prices took effect in 2013 and another is discussed to start in 2017. In a meanwhile, National Action Plan was adopted in December 2010 declaring the objective to reach 13% of energy from RES on final energy consumption by 2020. Since Hungary does not have sufficient conditions for production of hydro, solar and wind energy, important role within RES is played by energy with biogenic origin. This includes biomass, biogas and biofuels combustion. Energy production from RES in Hungary is also stimulated mainly by feed in tariffs that ranged from 0.0470 to 0.1060 EUR/kWh in 2014 (RONI 2014).

In December 2010, the National Action Plan for energy from RES in Poland was adopted. According to the document, the main RES for electricity production are biomass and wind. In Poland, certificate system has been the main support measure since 2005. The certificate of origin known also as green certificate is a document confirming that electric energy has been generated from RES. In the face of the on-going process of transition of the energy sector in Poland, in July 2013, the national regulations related to the energy sector (Energy Law from 1997) were partly amended (passed the law known as the energy three pack). These changes regulate *ia.* the electricity production in the micro-installations (less than 40 kW) (Act No. 984/2013 Coll.).

Currently, the most important regulation is the Act on Renewable Energy Sources adopted in 2015 (Act No. 478/2015 Coll.). This act introduces new forms of support for energy production from RES including ABPs, but it is supposed to come into effect as late as in 2017. In accordance with the Act, large biogas installations may continue in the certificate system or switch to the auctioning system of sale of electricity. Newly-constructed installations will function only within the latter system. The main idea of the system is that maximum amount and value of energy from RES which might be sold through auction system will be determined by the central government annually. Auctioning system is expected to grant the right to feed the national energy grid at a fixed price to the entities offering the most attractive energy prices. However, it is a system's drawback that the energy producers and investors lose the certainty of the price obtained and

guarantee of winning the auction what may be seen as obstacle in further development. Auctions will be held in the two groups. The division for new projects is carried out depending on the power (below and above 1 MW). Reference prices – the maximum acceptable level of production costs will be determined separately for each group. RES Act also requires that at least 25% of the volume allocated to auction was produced in small installations with a capacity of up to 1 MW.

In majority of the V4 countries, the smaller installed capacity of power plant, the higher feed in tariffs or other grants. This may enhance decentralization of energy production but recently decreasing feed in tariffs might be perceived as an obstacle for further development of power plants based on RES. Among analysed countries, the lowest tariffs are in Hungary and highest in Czech Republic. Nevertheless in comparison with Austria and Germany, where the production on energy from agricultural biogas is the most developed, the tariffs in the CECs are generally low (tab. 1).

Table 1. Feed in tariffs for energy produced from agricultural biogas in the CECs, Austria and Germany¹ as at January 1st, 2014

Country	feed in tariffs (€/kWh)
Czech Republic	0.1106 – 0.1499
Slovakia	0.1072 – 0.1252
Hungary	0.0470 – 0.1060
Poland	0.1093 – 0.1163 ²
Austria	0.1280 – 0.1960
Germany	0.0600 – 0.2500

Explanation: ¹Germany and Austria are among the countries with the most developed energy production from agricultural biogas in Europe; ²Auctioning system is supposed to start in Poland in 2017. Reference price for ABPs > 1 MW is about 0.1093 €/kWh, while for ABPs < 1 MW is about 0.1163 €/kWh.

Source: Developed by authors based on data from RONI (2014) and ERO (2016)

Legal framework on energy has considerably evolved over past two decades in V4 countries. Although the acts on energy were adopted earlier, particular acts and regulations on energy from renewable sources including agricultural bio-

gas addressing also forms of support for producers came into effect as late as after the accession of these countries into European Union. Among the analyzed countries, Poland is the only country that adopted quota system as a basic support mechanism. In the Czech Republic, Hungary and Slovakia, the price system based on feed in tariffs developed (Tab. 2). Financial support has become key stimuli for agricultural biogas energy production, but the redemption prices for this kind of green energy are relatively low in comparison with the countries with the most developed energy production from agricultural biogas in Europe – Austria and Germany. Moreover, price making systems and recent changes in legal framework might be seen as potential obstacle for further development of this sector as it raises uncertainty for producers in the context of profitability of production and return of investments. Therefore, the development of agricultural biogas energy production and agricultural biogas plants network in V4 countries is assessed.

3.2. Energy production from agricultural biogas in V4 countries

The onset of agricultural biogas plants in the EU is dated to mid-1980s. First biogas plants, including micro-scale installations (with installed capacity up to 100 kW), were established in Germany, Denmark and Austria (Fischer and Krieg, 2001). These countries are still among the leaders in agricultural biogas energy production. Germany is also distinct leader in agricultural biogas production, it covered over 80% of total agricultural biogas production in the EU in 2007 (Ebenezar et al., 2007). With considerable lag, Germany was followed by Austria, Netherlands, Denmark and Italy (Fig. 1).

In 2013, the total number of biogas plants in the European Union was 14,572. More than 62% (9,035) of them operated in Germany followed with huge lag by Italy nearing 10% (1,391) of all ABPs. In Germany, the number of plants was increasing by more than thousand a year in the period 2009-2011, but after the Renewable Energy Act EEG 2012, the German market was dramatically slowed down and the increase in the number of plants in 2013 was only 335 (Torrijos, 2016).

Table 2. Legal and financial conditions for the development of ABPs in the CECs

Country	the basic support mechanisms	the year of the first Act on RES ¹	available financial instruments	legal and financial barriers to development of the ABPs
Czech Republic	price system	2005	feed in tariffs payments guaranteed	temporary suspension of financial support for photovoltaic and biogas energy due to suspected abuse of support
Hungary		2010	feed in tariffs	the lowest feed in tariffs in the V4 region
Slovakia		2009	feed in tariffs tax breaks	uncertainty in profitability and return of investments for producers rising from energy price making system
Poland	quota system	2010	tax breaks preferential loans	low price of green certificates; low reference prices in auctioning system; market risk in auctioning system: the need to invest in the project preparation in the absence of any guarantee of support after losing tender

Explanation: ¹ – the year when the first regulation on promotion and financial support of energy production from RES was adopted

Source: Developed by authors

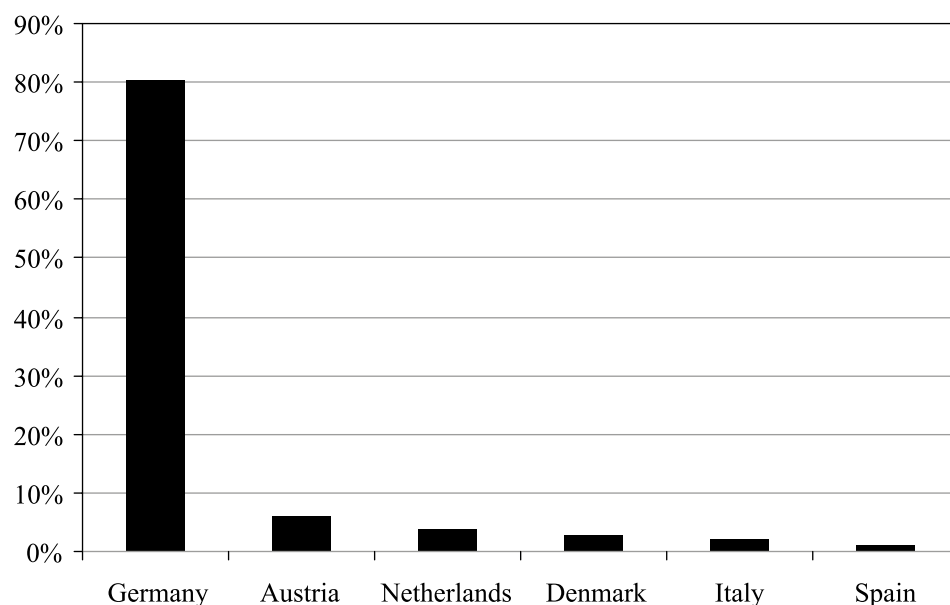


Fig. 1. Contribution of selected countries to total production of the agricultural biogas in the EU, 2007

Source: Developed by the authors based on the data from A Biogas Road Map for Europe (2009)

There are more sorts of biogas plants operating in the EU. By the source of biogas, following sorts are distinguished: landfill, sewage, agricultural residues and manure and other substrates – industrial food and beverage and bio-waste. Agriculture biogas plants that run on energy crops,

agricultural residues and manure have the biggest share (72%) in the total number of biogas plants. Such a big proportion is given by shares of such plants in the breakdown of leading biogas producing countries (Germany and Italy) which made up over 70% of total number of bi-

ogas plants in the EU. In Slovakia and the Czech Republic the proportion of ABPs on total number of biogas plants was 81% and 67% respectively, reaching proportions comparable with European leaders Germany (87%) and Italy (80%) in 2014. ABPs made up much smaller proportion in Hun-

gary (50%), and the smallest proportion among the V4 was recorded in Poland, only 20% (Torrijos, 2016) (Fig. 2). This is quite surprising as Poland and Hungary are countries with considerable better agricultural potential than the Czech Republic and Slovakia.

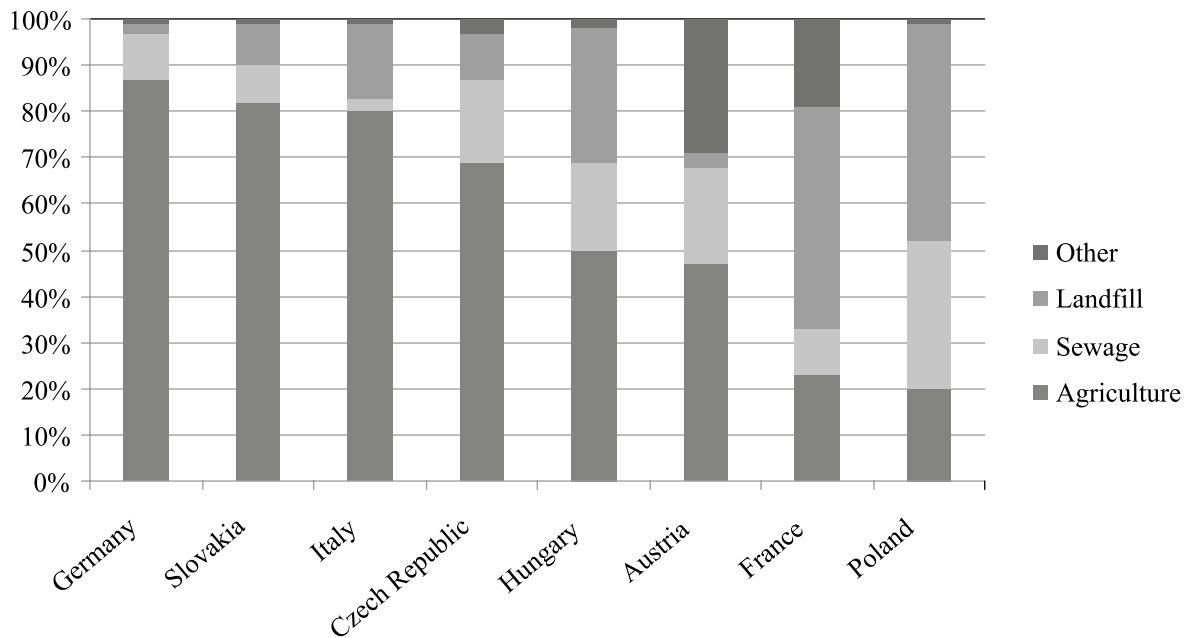


Fig. 2. Different types of biogas plants by country in Europe, Biogas Report 2014.

Source: Developed by the authors based on the data from Torrijos (2016)

The significance of the agricultural biogas as a source of energy is increasing in the EU and is likely to increase even more in the near future. It is predicted that by 2020, energy production based on agriculture will constitute 44% of the total bioenergy (this includes energy from woody and agricultural biomass and municipal and industrial waste) produced in the EU. In that number, the most energy from agricultural biogas plants in 2020 will come from France – 42.7 TWh (i.e. 20.4% of total energy produced by agricultural biogas plants in the EU) and Germany – 39.8 TWh (i.e. 19%) (Ebenezer et al., 2007). It is also projected the CECs, it means also V4, will gain important role in the agricultural biogas production in the EU (Simon and Wiegmann, 2009).

Energy production in ABPs has only short history in V4. Prior to the 21st century, energy from biogas was produced only by sewage or landfill plants. Production of energy from biogas obtained from agricultural waste or from the crops grown specifically for this purpose was stimulated by the ef-

forts of V4 to decentralize energy production and to raise the proportion of energy produced from RES. The biogas technologies were imported to the V4 mainly from Germany, Austria, and in Slovakia also from the Czech Republic. Agricultural biogas production has developed the most in the Czech Republic. It was the first from the CECs to produce energy from agricultural biogas already in 2002. Till 2013, the number of biogas plants has grown to 401 and installed capacity reached 363 MW (Martinát et al., 2013). So the Czech Republic became the fifth largest producer of energy from agricultural biogas in Europe. The largest numbers as well as installed capacity of ABPs are located in central part of the country and much lesser number of ABPs in north-western and north-eastern regions (Figs. 2, 3).

However, it seems the boom of biogas plants will be followed by stagnation of development. No biogas plant started operation in the country in 2015 and onwards. Cease in this energetic sector is determined by changes made in energy law that led

to temporal discontinuation in financial support for energy production from RES to the entities that started operation after 2013. The changes in law and energy from RES funding were made due to suspected misuse of funds intended to construction of photovoltaic and biogas plants.

The first ABP in Hungary was built in Nyírbátor (north-east) in 2003 and with installed capacity of 2.5 MW was ranked among the largest in the world that time. There were 34 ABPs with the capacity 34.2 MW by 2014 (Szabó et al., 2014). In contrast to the Czech Republic and Slovakia, agricultural biogas in Hungary is predominantly produced from agricultural waste and by-products. Energy produced from the crops cultivated specifically for this purpose is significantly lower, e.g., biogas energy from green maize constituted only 15% of total agricultural biogas energy produced in Hungary in 2012 (Fazekas et al., 2013). The majority of ABPs operates within premises of livestock husbandry farms and uses substrates from livestock husbandry, which constitutes more than 60% of all substrates for agricultural biogas energy production. In 2010 energy produced from agricultural biogas created barely 5% of total energy production from RES in Hungary. As indicated at Fig. 3, majority of ABPs operates in eastern, southern and north-western regions.

The beginning of energy production from agricultural biogas in Poland and Slovakia dates back to 2005. The first biogas plant in Poland was set up in Pawłówko (Northern Poland – Pomorskie Region), and the first one in Slovakia was built in Hurbánovo (South-Western Slovakia). The development of agricultural biogas plants in both countries was initiated by companies with foreign capital.

There were only eleven agricultural biogas plants in Poland in 2010, and in the next five years their number increased more than fivefold. There were already 58 biogas power plants at in 2014 with total installed power capacity of 65 MW and the number is still increasing, but relatively slowly. In Poland, certain concentration of ABPs is distinct in northern, western and south-western regions (Fig. 3), where large farms dominate, including these founded on the basis of former state owned farms. The average installed capacity of these installations was about 1.5 MW, and more. Since 2015, the investments are targeted primarily to smaller plants with installed capacity lower than 1 MW. Installed capacity of majority of them

is 0.999 MW. These also include biogas plants from eastern Poland established with the financial support from EU funds. They are characterised by similarity in terms of size: the installed capacity is 0.999 MW (Chodkowska-Miszczuk et al., 2016). Such significant number of agricultural biogas plants with an installed capacity limit of 0.999 MW results from the implementation of the provisions of the RES Act of 2015 related to the auction system. The adopted solutions divide renewable energy sources installations into two groups: projects with a capacity up to 1 MW and above 1 MW. Under these circumstances, agricultural biogas plants with a capacity of 0.999 MW are assigned to the first group and avoid price competition with large power units which can offer a significantly lower price for producing energy due to relatively lower costs of its production.

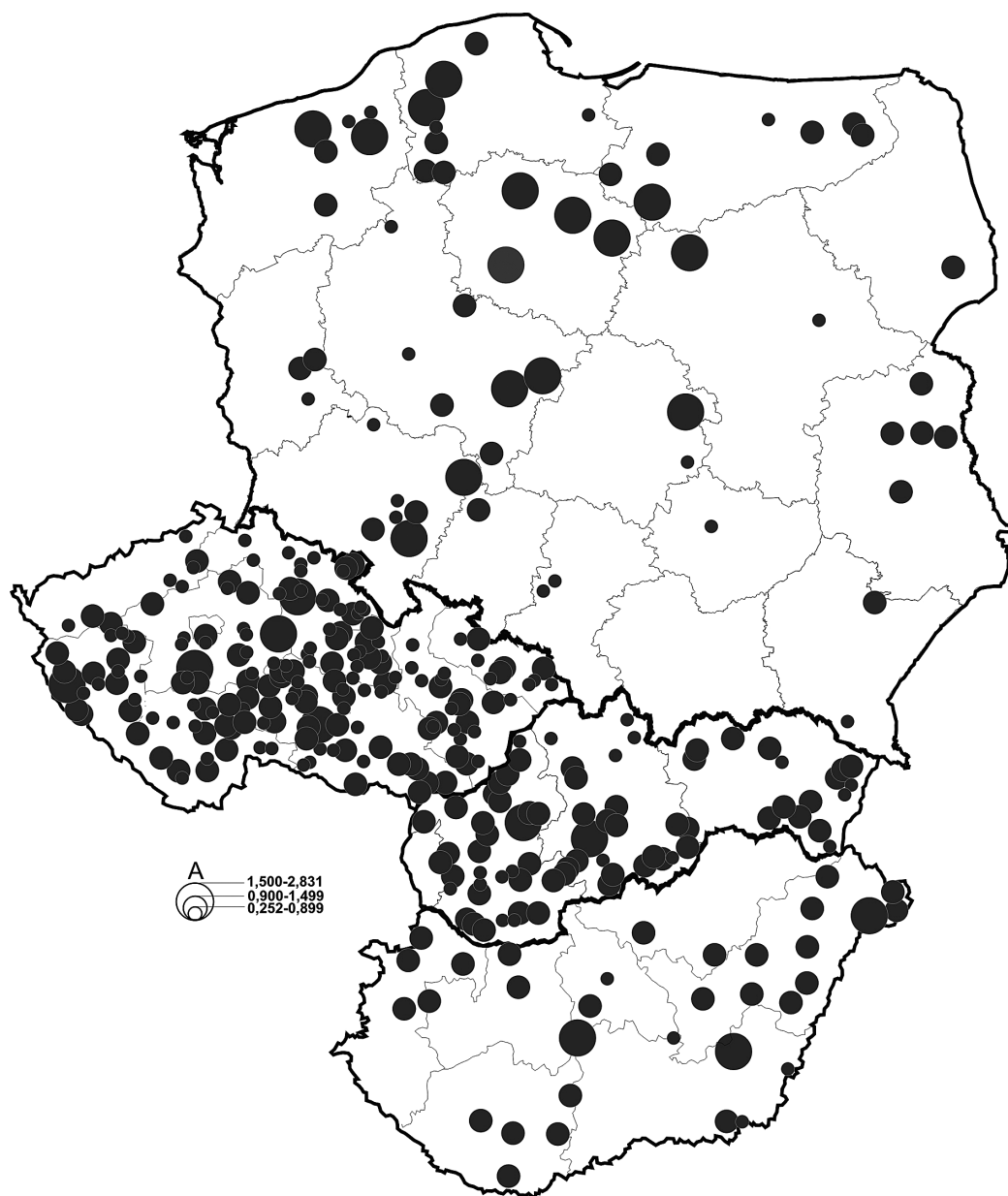
In Slovakia, first three plants with total installed capacity of 2 MW launched operation in 2005. More significant growth in the number of biogas plants started just after the adoption of the Law on the promotion of RES (Act No. 309/2009 Coll.). By 2011, there were 30 biogas plants in Slovakia with total installed capacity of 26 MW. By December of 2014, the number of agricultural biogas plants increased to 76 with total installed power capacity of 70 MW. The share on total installed capacity in Slovakia was 0.4%. Within Slovakia, the largest number of ABPs operates in Western Slovakia (33), in southern part of Central Slovakia and south-eastern part of Eastern Slovakia (Fig. 3) which are among the most fertile regions in the country.

Impressive growth in the number of biogas plants was instigated by the government support. Slovak government's most favoured RES is biomass, as it has the highest share of technical potential of all renewable energy sources (42%), and most of the biomass residue can be derived from agricultural waste (Lofstedt, 2008; Masár and Božík, 2009). Although further development potential is distinct (cf. Zachara, 2013), with decrease in feed in tariffs, the investments to the construction of new ABPs have lowered recently. National Action Plan for RES estimates the proportion of energy produced from biogas at total energy production from RES to 12% by 2020. ABPs operating by 2015 cover only 3.5%. The comparison of chosen indicators of current state of agricultural biogas energy production in individual V4 is provided in Tab. 3.

Table 3: Selected indicators on RES and ABPs in CECs, 2014

	Czech Republic	Hungary	Poland	Slovakia
Proportion of energy from RES in gross final energy consumption (%)	13.4	9.5	11.4	11.6
Number of ABPs	401	34	58	76
Installed capacity of ABPs (MW)	363	34	69	70
Average installed capacity of ABPs	0.9	1.0	1.2	0.9
Preferred substrate input for biogas production	maize silage	livestock husbandry	livestock husbandry	maize silage

Sources: developed by the authors based on the data collected from AMA (2016), Curkowski (2012), CZBA (2016), EUROSTAT (2015), Martinát et al. (2013), Rusňák et al. (2013), RONI (2014, 2015), Szabó et al. (2014)

**Fig. 3.** Distribution of agricultural biogas plants in V4 in 2014

Source: Developed by the authors based on the data collected from AMA (2016) and RONI (2015), Martinát et al. (2013) and Szabó et al. (2014)

The energy production in ABPs is developed the most in the Czech Republic followed with considerable lag by Slovakia. This seems surprising in the context of natural conditions (landscape, soils) that are better in Poland and Hungary. Nonetheless, it confirms decisive role of national legal framework and regulation in the biogas energy production development, including financial support policies.

On the other hand, while Czech Republic seems to be nearing the peak, there is still significant potential for growth in the other V4. In 2008–2009, over 80% of all ABPs in Visegrad region were located in the Czech Republic. However, this proportion started to lower in 2010 due to faster growth of ABPs numbers in other V4 countries.

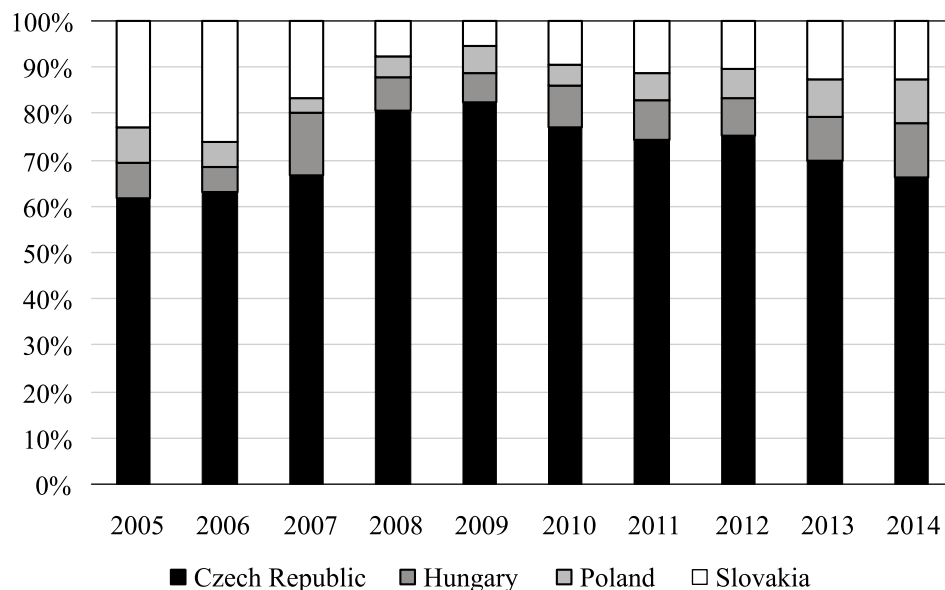


Fig. 4. Development of share of individual countries on total number of agricultural biogas plants in the CECs

Sources: Developed by the authors based on the data collected from AMA (2016), Curkowski, 2012, Martinát et al. (2013), CZBA (2016), Rusňák et al. (2013), RONI (2014, 2015), Szabó et al. (2014)

Adoption of legal framework on energy market in individual V4 enabled establishment of agricultural biogas plants in the region and their connection to transmission grids. However this basic legal framework (price system in Czech Republic, Hungary and Slovakia, and quota system in Poland) was not enough to stimulate development of agricultural biogas energy production significantly. Rapid growth in the number of ABPs and amount of energy produced from agricultural biogas was recorded in each country just after the support system took effect. Within Visegrad region the Czech Republic has become leader in energy production from agricultural biogas followed by Slovakia (Tab. 3 and Fig. 3). However, due to suspected misuse of funds intended to construction of photovoltaic and biogas plants, the financial support was temporarily suspended for all ABPs that started operation after

2013 in the mentioned-above countries. Lowering feed in tariffs and the way of price making process brought investors into uncertainty in Slovakia and Hungary what slowed down the development of agricultural biogas energy production in both countries. In Poland as a result of protracted process of changes in legal framework and transformation of support system, the dynamics of the development of the agricultural biogas sector has slowed down in recent years. Additionally a record-low price of green certificates (from May, 2016 < 0.0232 €/kWh, PPE 2016) significantly reduces the income of agricultural biogas plants and profitability of their operation. Moreover, the auctioning system brings a market risk regarding with auctions, low reference price for agricultural biogas (Tab. 2). It must be mentioned here, the EU funds from 2007–2013 provide the greatest financial support for investment

in agricultural biogas plants in Poland (Chodkowska-Miszczuk et al., 2016). This situation highlights the importance of direct financial support in agricultural biogas energy production. The results of conducted studies: significance of financial tools, including feed in tariffs and market risk relating to the quota system in development of ABPs, which are still relatively new in V4 countries are consistent to the research results provided by Pająk and Mazurkiewicz (2014). They indicated the certificate system is better for technology functioning for a long time on the energy market, while the system of guaranteed prices strongly stimulates the development of relatively new and small-scale energy installations.

4. Conclusions

Development under socialist central planning led in Visegrad countries to domination of one energy source, high energy intensity of national economies, centralization of the national energy markets, and last but not least energy dependence from Russia. This resulted to a need for decentralization of energy production and diversification of energy sources during the post-socialist transformation in favour of energy security of these countries. This was even enhanced by objective of the EU to increase the proportion of RES in total production of energy. All these circumstances are incentives to development of energy production from agricultural biogas.

The conducted studies shown that, the older law on energy was amended and new acts on energy issues were adopted since the early 2000s, even prior the EU accession. The new legal framework enabled operation of agricultural biogas plants. However, despite clear ecological benefits, the energy production from agricultural biogas was not economically viable. Further development was affected by the EU focus on prioritization of the renewable energy production. The Czech Republic was the first from V4 that adopted Act on RES and beside legal support, the financial support system for energy production from RES, including agricultural biogas was introduced. The Czech Republic employed price system, particularly feed in tariffs to support agricultural biogas energy producers.

This led to rapid growth in the number of agricultural biogas plants, and increase in the proportion of energy produced from agricultural biogas in total energy production in the country as well as total energy production from RES. Adoption of appropriate acts and measures to support green energy production was followed by other Visegrad countries. Czech Republic, Hungary and Slovakia employed feed in tariffs as a price system support, while in Poland a quota system support was adopted. At the beginning it employed certificate system which is currently being changed into auctioning system. After that, the role of agricultural biogas energy started to grow in all countries whether considering the number of agricultural biogas plants, their total installed capacity, or the proportion of energy produced from agricultural biogas at total national energy output. However, the Czech Republic remained leader in energy production from agricultural biogas followed by Slovakia what seem to be a result of direct financial support – generous support as indicated by the highest feed in tariffs among all Visegrad countries.

Generally, the analysis shown the adoption of legal framework was necessary step to enable agricultural biogas energy production in Visegrad countries, but itself it was not enough to stimulate development of agricultural biogas energy production significantly. Rapid growth in the number of ABPs and amount of energy produced from agricultural biogas was recorded in each country just after the support system took effect. The comparison among individual countries indicated strong dependence of agricultural biogas energy production on amount of guaranteed financial support. Due to expensive technologies necessary to launch ABP operation, producers need some guarantees on return of investments. Frequent changes of height of financial support, and its general lowering brought investors into uncertainty that resulted into slowdown in agricultural biogas energy production development.

Continuous improvement of technologies and their affordability might be seen as stimuli for further development of agricultural biogas energy production. However, it is clearly seen that dependence on state support is determining factor. Poland is recently in the process of changing its support system from certificates system to quota system. The changes were adopted already in 2015 but will take

effect in 2017. Nevertheless, the changes have already been manifested in changes of size-structure of ABPs and general slowdown in the growth of their number. Even more fundamental breakthrough occurred in the Czech Republic, where no agricultural biogas plant launched operation since 2014. This is due to temporal suspension of financial support for all ABPs finished after 2013, which took effect due to suspected misuse of funds intended to construction of photovoltaic and biogas plants. So the further development of agricultural biogas energy production seem to be still dependent of state support, although its economic competitiveness has been improving thanks to improvement of technologies and their affordability.

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