SPATIAL CONSEQUENCES OF BIOGAS PRODUCTION AND AGRICULTURAL CHANGES IN THE CZECH REPUBLIC AFTER EU ACCESSION: MUTUAL SYMBIOSIS, COEXISTENCE OR PARASITISM?

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Abstract
Renewable sources of energies and its support have been recently experiencing wide public debate in the Czech Republic that varies from agreement to complete denial. Nevertheless support from national and EU sources is factor that heavily influenced dynamic development of this sector in last decade. Anaerobic digestion plants are one of options for production of renewable energies (biogas in this case) that have experienced next to solar plants the most important increase of its installed capacities. This contribution first aims to analyse phenomenon of anaerobic digestion plants, its legal, strategic support, supporting financial incentives, individual types of such plants, and secondly based on available statistical data to analyse spatial distribution of agricultural anaerobic digestion plants. On basis of comparison of data for increasing biogas production and declining agriculture in regions of the Czech Republic basic consequences are deduced. In context of spatial distribution of agricultural anaerobic digestion plants structures of sowing areas and intensities of animal husbandry are shortly discussed. We can conclude that agricultural anaerobic digestion plants have been increasingly influencing the structure of sowing areas of agriculture of the Czech Republic and such facilities are in both agricultural sector and wide society perceived more as alternative source of income than contribution to environment protection, limitations for greenhouse gases production and climate change.

Key words: anaerobic digestion plants, agriculture, Czech Republic, spatial differentiation.

INTRODUCTION

The phenomenon of anaerobic digestion plants in the Czech Republic has been observed both in urban and mainly rural area during the last decade. Whereas in 2002 merely 11 anaerobic digestion plant installations with a total installed capacity of 4.19 MW were registered, at present (2013) there are 481 of such installations in the Czech Republic with the installed capacity of 363 MW (CZBA 2013). The Czech Republic, being the member of the European Union, has committed to producing at least 13% of energy from renewable energy sources by 2020 (National action plan for renewable sources of energy in the Czech Republic 2010), and thus further significant development of this sector can be expected. At present biogas makes 15.9% of all renewable energy sources (2013), rise up to 24% of total renewable energy sources (circa 417 MW of 1,738 MW in total) is expected by the end of this decade (CZBA 2013, National action plan for renewable sources of energy in the Czech Republic 2010). The number of anaerobic digestion plants will probably increase by approximately 60–80 plants by the year 2020 and the installed capacity by further 15% compared to present condition. It is a challenging task to identify how to affect (e.g. by using what types of tools and agents, which steps has to be done and in which order) spatial distribution of individual types and parameters of anaerobic digestion plants in different natural and socio-economic conditions. Decision about location of such facilities shouldn't be solely left to investors, but wider regional development issues have to be taken into account. Great synergy potential can be observed while applying new waste management policies. Also increased concentration of agricultural anaerobic digestion plants and small distances between each other might conclude in lack of input materials and pressure on farmers to use more crops for energy purposes instead of food.

Agricultural activities are closely linked to the issue of energies. Agricultural systems do not just consume energy (through transport of materials, heating etc.), but produce energy as well. It is indisputable that also food is a certain form of concentrated energy and by using suitable planting and breeding techniques increased energy potential of agricultural products is produced (Bauer et al. 2009). Recent debate on new tasks of agriculture as not only food producer, but as energy producer too, causes changes proposed for such crucial item as is basic definition of agriculture. While Encyclopedia Britannica propose classical approach that emphasize agriculture as the science or art of cultivating the soil, growing and harvesting crops, and raising livestock, Websters Encyclopedia shifted definition to more utilitarian and productive approach (The science or business of raising plants and animals useful to man. It implies the cultivation of the soil, the production and harvesting of crops, the care and breeding of livestock) and for example the Swedish National Encyklopedia (2011) admits even use of agricultural products for energy purposes in its definition (Agriculture is the use of land for farming or pasturage for production of provisions, forage and primary products for energy purposes or to further industrial improvement or preparation). Such shift in perception of agriculture implies significant changes in using of agricultural land.

It is obvious that from historical view technological advancements mirror both increasing demands for energy and increasing consumption by individual sectors of economy or households. Agriculture is not exception in these developments trajectories. Contemporary consumption of heating and electric energy in agricultural sector make 4,955 TJ per year (2011) according to data of the Czech Statistical Office and this value recalculated per agricultural hectare slightly increases every year. Moreover growing payments of agricultural farms for energies are projected to prices of agricultural products which became not competitive in comparison with cheaper agricultural imports. Such tendencies head agriculture towards systematic reduction of its activities which are accompanied by decrease of food self-sufficiency of the Czech Republic and increase of dependence on agricultural imports. With descending quality of food available for low budget consumers, question concerning growing food (in)-security rises (Pinstrup-Andersen 2009). Energy dependence on fossil fuels is another issue, which make agricultural sector vulnerable towards global energy market changes. As Weiland (2003) or Pöschl et al. (2010) point out, responses to climate change warnings could be found in production of renewable energies by farmers. Anaerobic digestion plants fall into category of facilities for renewable sources production that should be theoretically perceived by publish as less controversial, since they create not only alternative source of income for farmers (Yiridoe et al. 2009), but also suitable tool for rural development (Revelle 1979; Kostevšek 2013) through using of waste heat energy of anaerobic digestion plants for heating of local households, farms etc. Many controversies are linked to location of such anaerobic digestion plants and using of agricultural plants as input material for energy production (Upham 2009; Jørgensen and Andersen 2012).

Specifities of spatial diffusion of anaerobic digestion plants phenomena in urban and rural space are commented in studies of Barnett (1990) or Daxiong et al. (1990), who discuss crucial role of state support in initial stages of constitution of anaerobic digestion sector. As an important topic that is widely discussed in literature on renewable energies acceptance of such facilities was identified as crucial point both on household, municipal, regional and national level (Lantz et al. 2007; Jian 2009; Musall and Kuik 2011).

This contribution first aims to analyse the phenomenon of anaerobic digestion plants, their legislative, strategic support, supporting financial incentives, individual types of such plants, and second to analyse based on available statistical data spatial distribution of one of their types - agricultural anaerobic digestion plants. After comparing the anaerobic digestion and agricultural data we can deduce some elementary relations between agricultural slump in the regions of the Czech Republic and increase in number and capacity of agricultural anaerobic digestion plants. In brief, the structure of sowing areas and intensity of farm animal breeding in connection with the placement of agricultural anaerobic digestion plants is analysed, too.

LEGISLATIVE AND STRATEGIC PREREQUISITES FOR ANAEROBIC DIGESTION SECTOR DEVELOPMENT

Legislative and strategic arrangements are elementary prerequisites through which is the development of renewable energy sources in the Czech Republic formed. There are three legal regulations of power industry in the Czech Republic - Act no. 458/2000 Coll., on the Conditions of Business and State Administration in Energy Industries (the Energy Act) that regulates state and business conditions in electro energetics, gas industry and heating industry. Besides it deals with electricity generation licences and ensures that the producers of electricity from renewable sources shall be preferentially connected to the transmission system. The next is Act no. 406/2000 Coll. on Energy Management that regulates effective and considerate consumption of energy and energy sources.

The significant landmark in the history of renewable sources in the Czech Republic was the Act No.180/2005 Coll. on the promotion of electricity production from renewable energy sources (Act on Promotion of Use of Renewable Sources) that regulates, in accordance with the Directive 2001/77/EC of the European Parliament, the method of promoting the production of electricity from renewable energy sources, when one of its targets was the share of electricity from renewable sources in the gross consumption of electricity in the Czech Republic amounting to 8% in 2010, which was achieved due to the solar energy boom, and to create conditions for further increase of this share after 2010 (see above). This act also ensures that the producers of electricity from renewable sources who meet the requirements stipulated by the Energy Act shall be preferentially connected to the transmission system. The act also deals with the purchase prices for electricity from renewable sources and green bonuses, which are annually announced by the Energy Regulatory Office (ERÚ).

This act was replaced on January 1, 2013 by Act 165/2012 Coll. on promoted energy sources, amending the Act No.180/2005 Coll. This was in response to the Directive 2009/28/EC and

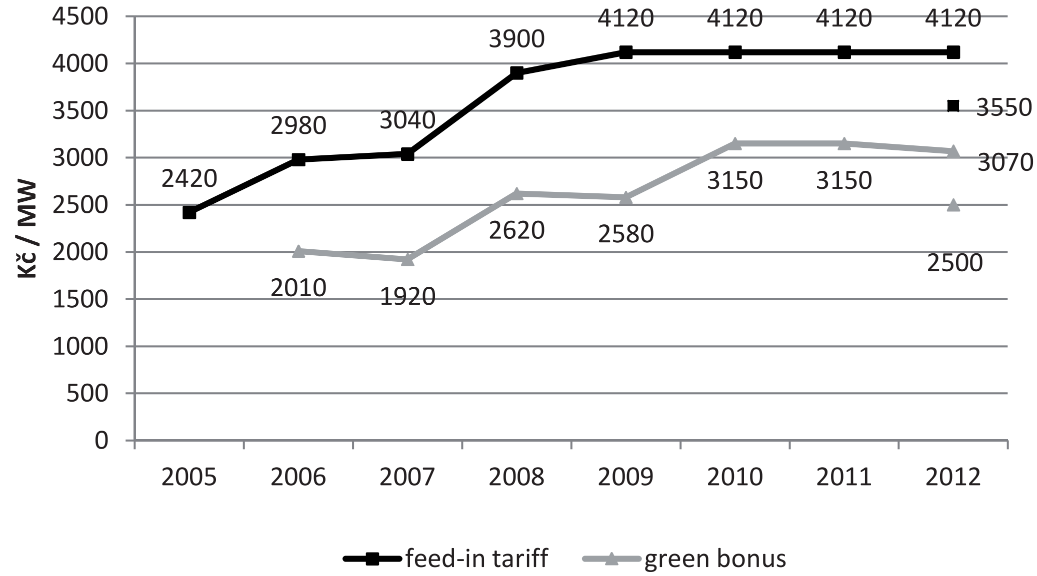

Figure 1 Development of purchase price for electricity and green bonuses for agricultural anaerobic digestion plants in the Czech Republic in 2005–2012 (in CZK/MW). Source: Energy Regulatory Office (ERÚ), own processing..

resulting National action plan for renewable sources of energy in the Czech Republic, 2010. One of the fundamental targets is the share of electricity from renewable sources in the gross consumption of electricity in the Czech Republic amounting to 13,5% in 2020, while "taking into consideration customer interests in minimizing the impacts of the promotion on energy prices for customers in the Czech Republic" (Article 1, Paragraph 2, Letter d of Act No.165/2012 Coll.) Basically further uncontrollable increase of energy from renewable sources should be prevented to reduce the range of its financial support, which is then included in the electricity price for the end-users and it is growing disproportionately. This target is fulfilled by following the support of purchase prices for electricity from renewable sources in the targets by National action plan for renewable sources of energy (2010) that quantifies the installed output of individual types of renewable sources for each year between 2010 and 2020. When achieving such annual target there will be no legal duty to support the new sources by way of special purchase prices or green bonuses.)

INCENTIVES FOR SUPPORT OF ANAEROBIC DIGESTION SECTOR

There are two ways how to support biogas production as renewable energy source under conditions of the Czech Republic. It is either by support for anaerobic digestion plants constructions, or by securing purchase prices for electricity, or possibly by support for combined heat and electricity production by way of guaranteed purchase prices and green bonuses (the so called feed-in tariff). The support for biogas production by means of feed-in tariffs started in the Czech Republic in 2002. It gets revised annually and it is valid only for new installations in the given year, the purchase price of the former sources is valorised. Since 2006, when the Act No. 180/2005 Coll. came into force, 15-year payback considering the investment in anaerobic digestion plant construction has been guaranteed. The guaranteed purchase prices for electricity and green bonuses for agricultural anaerobic digestion plants, which are shown in Figure 1, have not experienced such significant dynamics as it is with solar

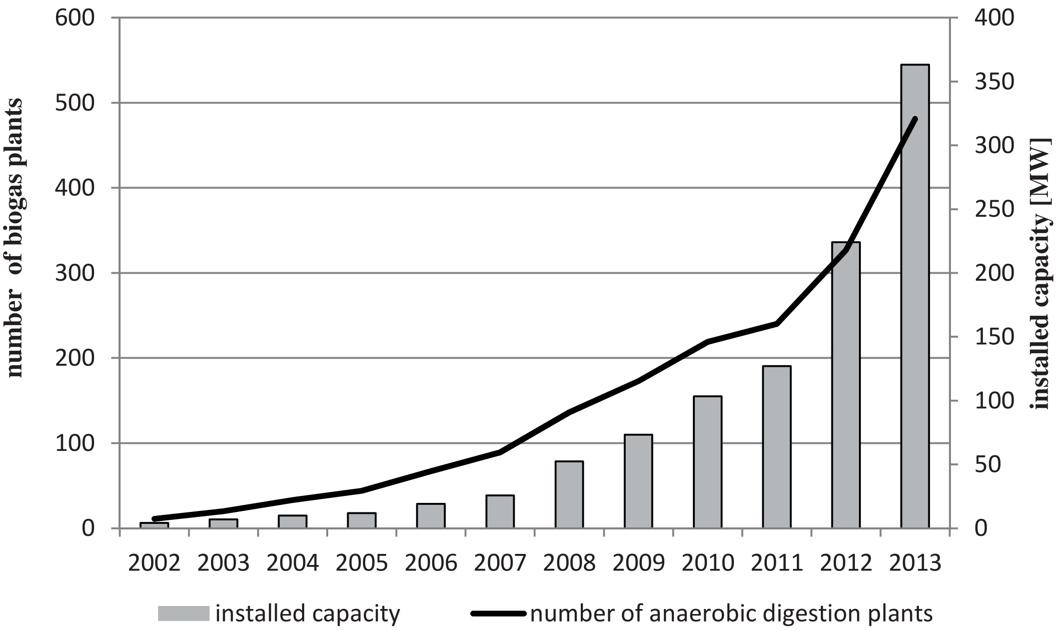

Figure 2 Development of installed output and number of anaerobic digestion plants in the Czech Republic in 2002–2013. Source: Energy Regulatory Office (ERÚ), own processing.

energy (for example 12 250 CZK until 2010), and since 2009 they have been rather steady amounting to 4 120 CZK per 1 MW of electricity. Only in 2012 the support for anaerobic digestion plants that did not meet the additional criteria to use at least 10% of heat produced in anaerobic digestion plants decreased. These anaerobic digestion plants with their support reached the level of the anaerobic digestion plants processing waste (purchase prices for electricity 3 550 CZK/MW and green bonus 2 500 CZK/MW), which is generally lower under the Czech conditions.

The average investment costs for anaerobic digestion plant quoted by Dvořáček (2009) oscillate around approximately 100 thousand CZK/kW of installed output regarding the agricultural anaerobic digestion plants. In case of anaerobic digestion plant focused on waste processing the cost varies between 200 and 250 thousand CZK/kW. The difference in cost is due to their distinct technology used and difference in raw materials processed, and here the economies of scale can be applied, where it states that the lower the installed output of the anaerobic digestion plant, the higher the investment cost per kW.

Construction of the majority of anaerobic digestion plants in the Czech Republic was co-financed from public finance. The primary sources of public finance were from Rural Development Programme of the Czech Republic conducted by the Ministry of Agriculture, next was Operational Programme Environment – Priority 3: Sustainable use of energy sources (Ministry of the Environment) and Operational Programme Enterprise and Innovation – Priority Axis 3: Effective Energy (Ministry of Industry and Trade). The importance of subsidies for anaerobic digestion sector is apparent from Figure 2, where the first significant increase in number of plants can be noticed in 2008, i.e. the period of implementation of approved projects for anaerobic digestion plants construction from the first call of Rural Development Programme. By 2012 there had been 178 projects supported with the amount of 3,147 billion of CZK (Diversification into non-

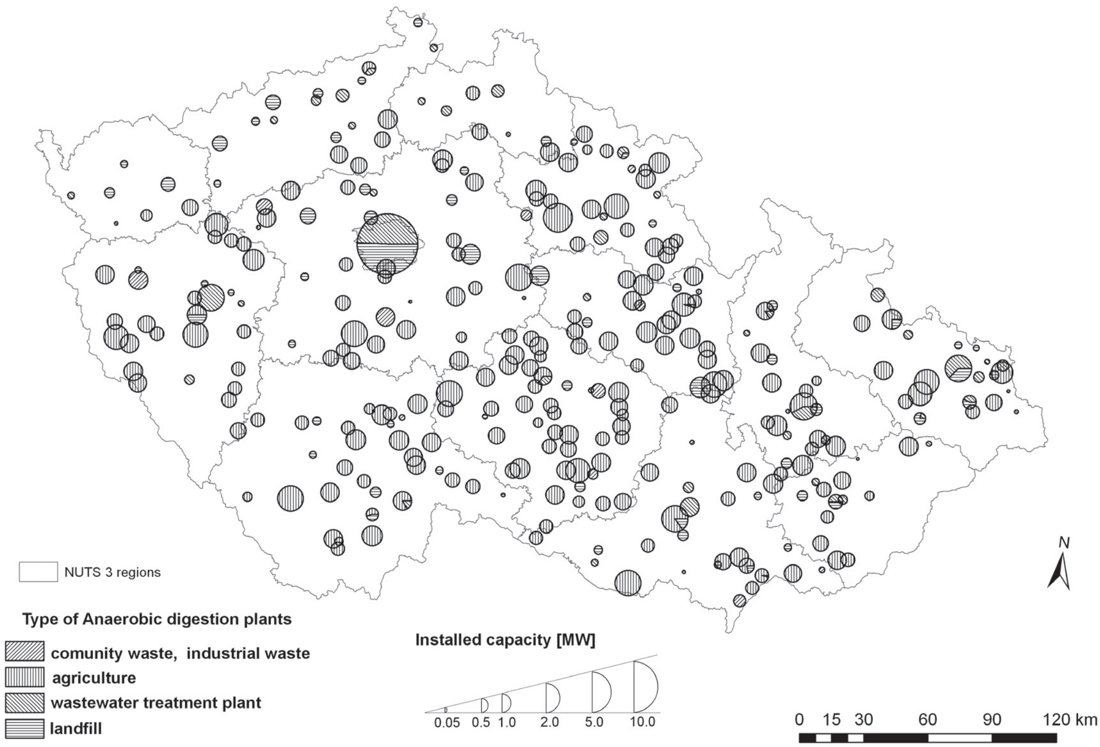

Figure 3 Spatial distribution of basic types of anaerobic digestion plants in municipalities of the Czech Republic in 2012. Source: Energy Regulatory Office (ERÚ), own processing.

agricultural activities III.1.1.b, Support for business creation and development III.1.2.b), while the maximum amount of support was between 40 and 60% according to the size of the enterprise (Rural Development Programme of the Czech Republic 2007 – 2013, 2010). Average amount of subsidy for one anaerobic digestion plant of agricultural type was 17,7 million CZK. From the Operational Programme Environment there were 6 projects supported for 142 million CZK, and from the Operational Programme Enterprise and Innovation there were 35 projects with the amount of 520 million CZK (both the projects of agricultural and waste anaerobic digestion plants were supported), more then 3,8 billion CZK altogether for all above mentioned biogas sources. It can be observed that majority of above mentioned subsidies was invested in agricultural anaerobic digestion plants; in case of other types of anaerobic digestion plants (see below) such subsidies are not too common.

Agricultural anaerobic digestion plants, which will be discussed widely in the following text, process purposefully grown vegetation biomass (corn maize, grass, perennial fodder plants, etc.) and side products of animal husbandry (manure, liquid manure, etc.). Stabilized rests after fermentation process (digestate), can be used as fertilizer (Marada et al., 2008). Spatial distribution of anaerobic digestion plants in the Czech Republic is illustrated in Figure 3. Apart from the agricultural type of anaerobic digestion plants, also anaerobic digestion plants processing industrial and communal waste, plants located on sewage water treatment plants (in urban space mainly) and plants located on landfills making use of the so called landfill gas. As for average size of anaerobic digestion plants in the Czech Republic it can be stated that in last three years decrease of this indicator was experienced as consequence of relatively smaller farms as subvention applicants (in comparison to previous period before 2011).

AGRICULTURAL ANAEROBIC DIGESTION PLANTS AND AGRICULTURAL DECLINE

In the next chapter we will briefly discuss agricultural anaerobic plants. The objective is to analyse the links between agricultural decline in the regions of the Czech Republic and increase of number of the anaerobic digestion plants. This analysis is performed at the level of regions (13 units of NUTS3 level excluding Prague as predominantly urban space) and at the level of districts (77 units of NUTS4 level). Data used for analyses is derived from surveys of the Czech Statistical Office (www.czso.cz), both from agricultural censuses (2000, 2010) as well as from inventories of sowing areas (2004, 2012) and inventories of animal husbandry (2004, 2013). Data on changing structure of agricultural and arable land (2000, 2004, 2010, 2012) comes from the Czech Office for Surveying, Mapping and Cadastre (www.cuzk). For analyses of anaerobic digestion plants and their attributes data from the Energy Regulatory Office (www.eru.cz) and Czech Biogas Association (www.czba.cz) was used.

Agriculture of the Czech Republic has experienced significant structural changes in the last two decades. Centrally planned policy of agriculture that highly influenced production and organization structure of agriculture of the former Czech Republic was left behind since 1990s in favour of liberalization, loosening of customs barriers and higher level of agricultural and food imports into the Czech Republic. Processes such as privatisation (transfer of state-owned property into the private hands) and restitutions (returning of confiscated property to their original owners) of agricultural land or properties deeply influenced the range and structure of agricultural production of the Czech Republic. Since the new millennium the Common Agricultural Policy of European Union has been the most influential factor of the Czech agriculture, first in the form of the Pre-Accession Programmes and after the joining of the European Union (2004) it became its standard application (Věžník a Konečný, 2011). Slumps of agriculture in the Czech Republic with changes of its structure are regionally differentiated depending on the environmental conditions and historical preconditions of agricultural use of the given area (Martinát et al., 2009).

If we consider the agricultural sector of the Czech Republic as a whole, then in two decades since 1990 its gross agriculture production decreased by 31% to 17, 4 thousand of CZK (per 1 hectare of agriculture land in fixed price of 1989), cattle numbers reduced by 61%, pig numbers went down by 67%, sowing areas of common crops such as potatoes decreased while the sowing areas of energy crops increased. In the same period the food consumption remained more or less the same though, so the majority of domestic consumption is covered by the imported food from the countries both within and outside the European Union. In connection with the decline of the Czech agriculture a range of unused buildings and premises are emerging in rural space, which are called brownfields (Svobodová a Věžník, 2009, Navrátil et al. 2010, Klusáček et al., 2011, 2013). Farmers are even more forced to develop and intensify their alternative agricultural or non-agricultural activities which account for still higher share of their total income. Such activities include growing alternative crops, organic farming practices (e.g. Ilbery and Maye, 2011), produce and sale of products directly from the farm, tourism activities (e.g. Navrátil et al., 2009). This type of land use includes purpose-grown energy crops (e.g. oilseed rape) or crops grown specifically for the use of anaerobic digestion plants (corn maize, fodder plants, etc.).

Basic information on spatial distribution of agricultural anaerobic digestion plants stations within regions of the Czech Republic could be found in Table 1. From the overall number of these stations in the Czech Republic (211 facilities) one fifth was made by agricultural anaerobic digestion plants located in the Vysočina Region (41 facilities), twenty and more is registered in 5 other regions (South Bohemia, Central Bohemia, Plzeňský, Královehradecký and Pardubický Regions), on the other hand the smallest number can be found in north-western belt of regions in Bohemia (Karlovarský, Ústecký a Liberecký kraj). It can be stated that fewer agricultural anaerobic digestion plants can be found in mountain regions and regions with significantly worse natural conditions for agriculture. Not very surprising results were offered by analysing the installed capacities of agricultural anaerobic digestion plants in the studied regions of the Czech Republic (see Table 1). On the other hand, promising interpretations could be carried out for average installed capacities of agricultural anaerobic digestion plants in individual regions. Despite of lower number of such station (9), it is the Moravian-Silesian Region in eastern part of the Czech Republic where average installed capacity of plants exceeded 1 MW. This average size was achieved approximately by stations in Pardubický Region too. On the other hand, figures considerably below average of the Czech Republic were calculated for Zlínský, South Bohemia and Vysočina Region (circa 0,7 MW). With respect to the fact that last two above mentioned regions are the ones with the most agricultural anaerobic digestion plants (27, 41 respectively), certain specifics can be noticed, which cannot be explained explicitly though. In case of the Moravian-Silesian Region there is a connection between local anaerobic digestion plants and large scale facilities for animal husbandry (Velké Albrechtice by Bílovec, Stonava or Pustějov).

If a group of agricultural anaerobic digestion plants (211 facilities) is broadened to all types of anaerobic digestion plants that operate in the Czech Republic, 342 such anaerobic digestion plants facilities could be counted (from September 2012, when examined database of anaerobic digestion plants was developed, until March 2013 the number of all anaerobic digestion plants in the Czech Republic increased to 481 facilities). Nevertheless even this perspective didn't show any important regional difference than the one portrayed above. The only significant difference was found for Ústecký Region, where the majority of anaerobic digestion plants facilities (16 of 20) are based on sewage water plants, not on agriculture. Even if we exclude this region from the group of regions with significantly lower number of anaerobic digestion plants, there are still two other regions (Karlovarský, Liberecký regions) with problematic public reception of this type of facility for renewable energy production. A relatively lower spatial extent of both regions has to be taken into account, too.

Another indicator that was analysed to identify interregional specifics of distribution of agricultural anaerobic digestion plants in the Czech Republic is the frequency of their occurrence among agricultural entrepreneurs. Group of all farms in the Czech Republic gathered by agricultural census (Agrocenzus 2010) was reduced to agricultural companies with legal person status as the majority of agricultural anaerobic digestion plants operators is made almost solely by legal persons. As Table 1 shows, for one agricultural anaerobic digestion plants 7-10 agricultural companies (of legal persons), thus highest frequency of occurrence could be counted in belt of regions consisting of Vysočina, Pardubický and Královehradecký Regions (plus Plzeňský Region in western Bohemia). Second group of regions, where similar frequencies were calculated (circa 14-20 companies), are areas both in the eastern part of the Czech Republic (Moravian-Silesian, Olomoucký, and Zlínský regions) and north-south belt in Central and South Bohemia. As relatively independent the South-Moravian Region was identified (circa 27 companies per one agricultural anaerobic digestion plant). Group with the less importance of anaerobic digestion plants in agricultural companies was not surprisingly formed by north-western belt of regions in Bohemia (Ústecký, Karlovarský and Liberecký regions).

As the next step agricultural anaerobic digestion plants were evaluated according to average price of 1 m^2 of agricultural land where this facility is located (average per region). The main aim was attempt to analyse dependence of location of anaerobic digestion plants on agricultural land quality. Authors take into account fact that sowing areas of crops used as input material are located not just on one cadastral area, but in more of them. Nevertheless distances between individual pieces of agricultural land are usually not so big, thus with certain level of generalisation it can be assumed that average prices approximately match to prices of set of cadastral areas located around farm. As come out from the inter-regional comparison, the highest average prices of agricultural land with anaerobic digestion plant can be found in Olomoucký, Zlínský and the South Moravian Region (more than 8 Kč / m^2), around average

Table 1 Agricultural anaerobic digestion plants in regions of the Czech Republic (as of September 2012). Sources: Energy Regulatory Office (www.eru.cz), Czech Statistical Office (www.czso.cz), Agrocensus 2010 (www.czso.cz), Regulation no. 412/2012 on setting the list of cadastral areas with average basic prices of agricultural land; own processing.

Region	A	B	C	D	E	F	G
Central Bohemia	24 / 39	20.404	77.7	0.85	3.1 / 3.7	18.7	6.68
South Bohemia	27 / 36	19.443	92.9	0.72	4.0 / 6.2	14.4	3.51
Plzeňský	22 / 30	18.184	80.4	0.83	4.8 / 7.1	10.8	3.84
Karlovarský	2 / 7	1.114	48.9	0.57	0.9 / 2.1	40.0	2.34
Ústecký	4 / 20	2.977	39.2	0.74	1.1 / 1.6	41.8	6.08
Liberecký	2 / 7	1.556	55.7	0.78	1.1 / 2.4	65.0	2.84
Královéhradecký	20 / 28	17.669	91.5	0.88	6.4 / 9.2	9.6	5.74
Pardubický	20 / 27	19.058	85.1	0.95	7.0 / 9.6	9.3	5.63
Vysočina	41 / 48	30.834	94.1	0.75	7.5 / 9.7	7.1	3.78
South Moravia	16 / 32	14.101	79.8	0.88	3.3 / 4.0	26.8	8.48
Olomoucký	14 / 23	10.632	78.5	0.76	3.8 / 5.1	14.0	10.07
Zlínský	8 / 15	5.387	79.5	0.67	2.8 / 4.4	19.1	8.53
Moravskoslezský	9 / 27	9.315	63.4	1.04	3.4 / 5.5	18.8	5.33
Czech Republic	211 / 342	171.421	77.7	0.81	4.1 / 5.7	14.6	5.52

Note: A – number of anaerobic digestion (AD) plants (agricultural / overall)
B – installed capacity of agricultural AD plants (MW)
C – share of installed capacity of agricultural AD plants on overall capacities of AD plants (%)
D – average installed capacities of agricultural AD plants (MW)
E – number of kW per 100 hectares of agricultural / arable land
F – number of farms (legal persons) per 1 agricultural AD plants
G – average price of agricultural land of cadastral area. where agricultural AD plants are located (CZK/m^2)

of this price for the Czech Republic as a whole (5.52 CZK/m^2) five regions were gathered (Central Bohemia, Ústecký, Královehradecký, Pardubický and Moravian-Silesian Region). On the other hand, the lowest average prices were recorded both in two regions with the highest number of agricultural anaerobic digestion plants (South Bohemia, Plzeňský and Vysočina Region) and in Karlovarský and Liberecký regions, where just two localities with this type of stations were identified. Specifity of the South Bohemia and Vysočina regions can be seen in overall lower level of prices of agricultural lands (with respect to natural conditions), nevertheless also individual agricultural anaerobic digestion plants are usually located here in areas with complicated natural conditions for agriculture (Kunžak in Česká Kanada, Chroboly, Soběšice or Lenora in the Šumava Mts., Větrný Jeníkov and Čihošť in the Českomoravská vrchovina Highland or Klokočov in Oderské vrchy Highland). On the other hand, also localities with very good soil quality (more than doubled in comparison to the average price in the Czech Republic) could be found between localities with agricultural anaerobic digestion plants in other regions. Such localities could be found in Roštěnice in Vyškovská brána basin, in Haňovice in Litovelské Pomoraví, Hněvotín in the Olomouc Region or Dobrovice near Mladá Boleslav, where wastes after sugar beet processing from local sugar refinery is processed.

SPREADING OF AGRICULTURAL ANAEROBIC DIGESTION PLANTS

Information on intensity of spatial dynamics, i.e. how agricultural anaerobic digestion plants have been spreading in rural space of the Czech Republic since 2006, can be seen in Figure 4. It is necessary to emphasize that crucial precondition for such dramatic increase in number of these facilities is caused by national and European subvention policies. Plants without any incentives are rather exceptional in the Czech Republic (as an example, agricultural anaerobic digestion plants in Palkovice, Moravian-Silesian Region, or in Lípa, Vysočina Region can be mentioned – Trnavský 2011). On the other hand, in case of all other types of anaerobic digestion plants (based on sewage water, landfill, household waste and industrial waste) it is obvious that such facilities are usually built without incentives. The above mentioned cases indicate though that even in agricultural sector this solution is possible.

From the historical point of view, origins of anaerobic digestion plants in the area of the Czech Republic can be traced to 1970s, when first anaerobic digestion plant was built in Třeboň (South Bohemia Region). This plant was based on processing of waste materials from local waste water treatment, and also pig slurry from nearby large scale piggeries (circa 30 thousand pig heads) was processed here. However, such facility was perceived more of an experiment in those days than a way how to process agricultural waste.

First attempts to follow up this pioneer anaerobic digestion plant appeared 30 years later. However merely 6 agricultural anaerobic digestion plants operated in the Czech Republic in 2006 and only two of them had installed capacity larger than 1 MW (Velký Karlov, South-Moravian Region, and Klokočov, Moravian Silesian Region). On the contrary, nowadays the largest installed capacity of such facility was identified in Kralovéhradecký Region, namely in Králíky municipality (2,5 MW), but generally average size of these facilities decreased.

It is obvious that in regions with slightly worsenned natural conditions for agriculture higher occurence of agricultural anaerobic digestion plants was recorded. However, plants located on good soil quality could be found too (see below), but from general point of view the above mentioned dependence might be observed. The next issue, very important for spatial pattern of studied facilities, is the level of acceptance of anaerobic digestion plants by both local / regional population and local / regional administration. The level of entrepreneurial activities of farmers, their adoption of new technologies and conformity with energy use of agricultural crops could be stressed as significant factors when evaluating spatial distribution of agricultural anaerobic digestion plants. The importance of examples of best (or worst) practices should not be underrated. In regions where examples of successful operation of agricultural anaerobic digestion plant were recorded (Pacov in Vysočina Region, Třeboň in South-Bohemia Region, Letohrad in Pardubice Region) expansion of such plants seems to be more intensive, while if some negative examples occur (problems with technology, lack of input materials, environmental problems in municipality, etc.), expansion tends to slow down. As an example of problematic anaerobic digestion plant, the plant in Velký Karlov (South Moravian Region) can be mentioned, also showing up in the titles of local newspapers and media (Anaerobic digestion plant in Velký Karlov will have to pay a 5 milion Czech crowns penalty - 2009; Who will stop anaerobic digestion plant in Velký Karlov - 2010; There will not be new anaerobic digestion plant in the Znojmo area – organizing petition was a help - 2012).

Relatively more dense clusters of agricultural anaerobic digestion plants can be found in rather peripheral rural areas (see Figure 4) with more complicated natural conditions for productive farming (south-west belt from the South-Bohemia through Českomoravská vrchovina Highland to the north of Orlické hory Mts. or foothills of the Šumava Mts. in western Bohemia. Increased numbers of such plants can be also found in peripheral locations between individual regions. Such tendency is clearly visible on boundaries of the Central-Bohemia Region (with higher intensity in the west and in the north, and less intensity in the south). The case of Central Bohemia with growing suburban

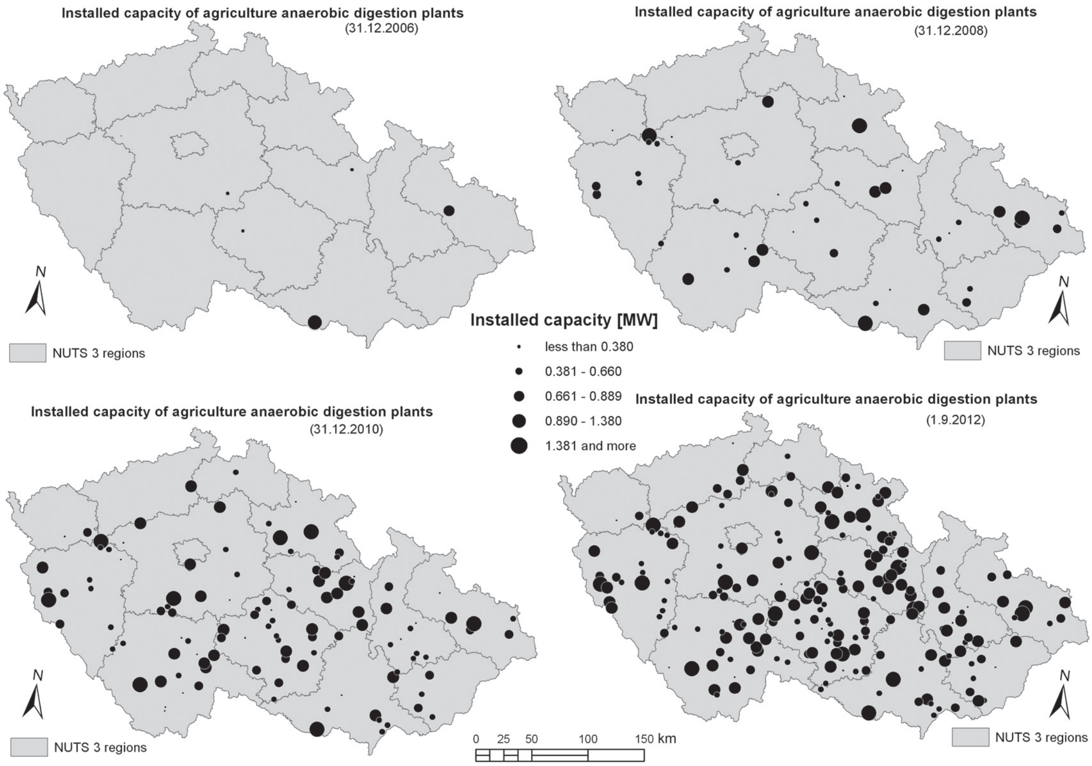

Figure 4 Dynamics of growth of number and installed capacities of agricultural anaerobic digestion plants in the Czech Republic (2006, 2008, 2010, 2012). Source: Energy Regulatory Office (ERÚ), own processing.

municipalities around Prague can be viewed as an example of possible effect of newcomers who can play an important role in refusing anaerobic digestion plants in their locality (as obvious from titles of articles from local newspapers – Population of Lány protested agains anaerobic digestion station, stink endanger them; Demonstration in Lány again anaerobic digestion plant etc.).

CONSEQUENCES OF AGRICULTURAL CHANGES

Agricultural anaerobic digestion plants were also evaluated in context of agricultural changes that were experienced in individual districts (77) and regions (13) of the Czech Republic. Changes of sowing areas of individual crops and changes in the intensities of types of animal husbandry were examined to identify the common consequences of the growing number of agricultural anaerobic digestion plants in certain regions. The starting point for analyses was an assumption that the more agricultural anaerobic digestion plants with higher installed capacities occur in regions, the more changes in agriculture should be recorded in these regions. A set of sowing areas of individual crops was evaluated, nevertheless, sowing areas of corn maize as the most common input material for digestion were deeply analysed. Concerning the individual types of animal husbandry the highest attention was paid to pig breeding (see Figure 5), cattle and poultry breeding.

It can be stressed that increased shares of sowing areas of corn maize together with increased intensities of cattle breeding partially correlate with areas where higher amount of agricultural anaerobic digestion plants occur. In case of corn maize it is a belt that covers areas from the Šumava Mts. in the south-western Bohemia across the Jihočeské pánve

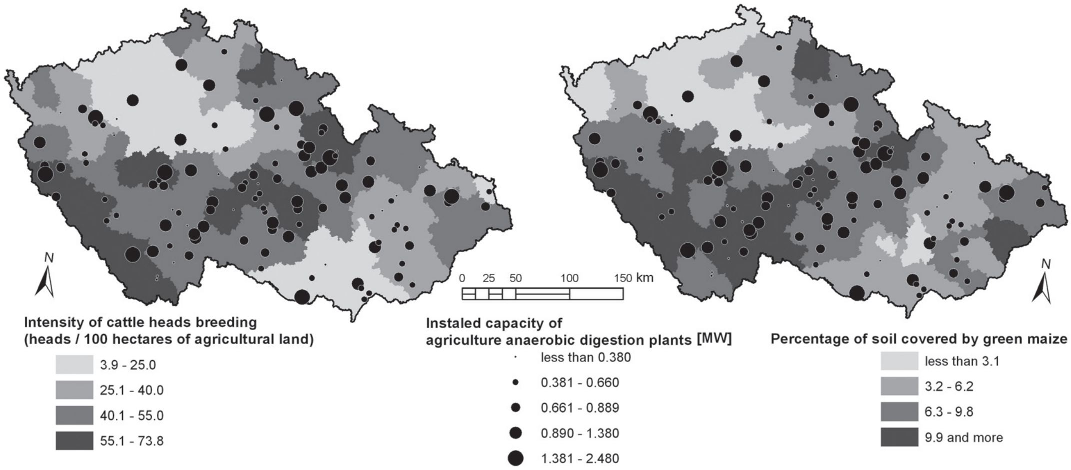

Figure 5 Intensity of agriculture (cattle breeding, sowing areas of corn maize - 2010) and spatial distribution of agricultural anaerobic digestion plants (2010). Source: Energy Regulatory Office (ERÚ), own processing.

Table 2 Changes of sowing areas covered by corn maize in the regions of the Czech Republic in 2004–2012. Source: Czech Statistical Office (www.czso.cz); own processing.

Region	Share of sowing areas covered by corn maize (%)		Difference
	2004	2012	
Central Bohemia	8.9	6.3	−2.6
South Bohemia	11.6	12.1	0.5
Plzeňský	12.0	13.4	1.4
Karlovarský	3.8	4.0	0.2
Ústecký	4.8	3.0	−1.8
Liberecký	8.9	8.4	−0.5
Královéhradecký	9.4	10.1	0.7
Pardubický	9.1	11.0	1.9
Vysočina	10.2	12.5	2.3
South Moravia	5.1	5.1	0.0
Olomoucký	6.6	8.3	1.7
Zlínský	8.7	8.4	−0.3
Moravskoslezský	6.1	7.5	1.4
Czech Republic	8.1	8.7	0.6

Table 3 Selected basic features of animal husbandry in the regions of the Czech Republic (2004-2013).
Source: Czech Statistical Office (www.czso.cz); own processing.

Region	Cattle breeding		Pig breeding		Poultry breeding	
	A	B	A	B	A	B
Central Bohemia	22.1	−3.8	53.5	−30.3	886.1	62.0
South Bohemia	42.9	−1.9	47.5	−59.4	875.8	−35.1
Plzeňský	42.7	0.7	46.1	−47.1	966.0	17.1
Karlovarský	31.6	14.4	3.1	−95.9	323.4	−24.7
Ústecký	13.2	−17.8	47.0	−39.4	806.4	−26.5
Liberecký	32.2	18.9	31.7	−51.1	85.8	−58.7
Královéhradecký	36.2	−7.3	44.6	−63.9	1,198.3	30.8
Pardubický	41.8	−5.1	74.4	−25.3	1,702.8	92.9
Vysočina	51.5	−1.7	78.1	−38.0	110.3	−72.3
South Moravia	14.0	−23.4	49.2	−63.9	857.8	−31.0
Olomoucký	32.4	−11.1	42.8	−62.1	215.5	−31.8
Zlínský	30.1	−6.7	94.4	9.1	622.4	−52.4
Moravskoslezský	27.6	−5.5	30.7	−68.4	649.6	−38.3
Czech Republic	32.0	−4.4	53.0	−48.2	777.3	−6.9

Note: A – intensity of breeding (heads per 100 hectares of agricultural land) in 2013
B – changes of breeding intensity (2004–2013, %)

Basins and further to the north to the foothills of the Orlické hory Mts. Spatial consequences of cattle breeding intensities seem to be similar. For more detailed consequences for agriculture of individual regions as for changes in animal husbandry breeding (2004-2013) and corn maize growing (2004-2012) please see Tables 2 and 3. It is obvious that regions with increases of sowing areas of corn maize match to regions with highly developed agricultural anaerobic digestion plants sector (Plzeňský, Region, South Bohemia Region, Vysočina Region, Pardubický Region). Regarding biogas yields of individual crops and wastes mentioned above, a very low correlation to areas with higher intensities of poultry breeding can be highlighted (see Figure 6), as poultry slurry provide much more energy re-use (four times more) than cattle slurry which is used as one of the most obvious input for digestion. Very high biogas yield is of cereals or rape seed (three times more than corn maize). On the other hand surprisingly low biogas yeild is in pig slurry, just half the cattle slurry (Banks et al., 2006 – see Figure 6).

Because of lack of recent data and comparable data at district level (77 units), further analyses were performed using data for regions (13 unit, Prague was excluded from analyses). As stated above, the basic material used as an input for agricultural anaerobic digestion plants in the Czech Republic are corn maize and wastes after animal husbandry (manure and slurry). Corn maize is a crop originally cultivated as fodder for animals, however with a two-thirds decline in numbers of animals in the Czech Republic over the last two decades, this crop has started to be used more as a plant processed in anaerobic digestion plants for energy generation. As it is obvious from Table 2, after EU accession of the Czech Republic in 2004, sowing areas of corn maize have not experienced any dramatic increases. Only one minor increase in sowing areas by 0, 6%

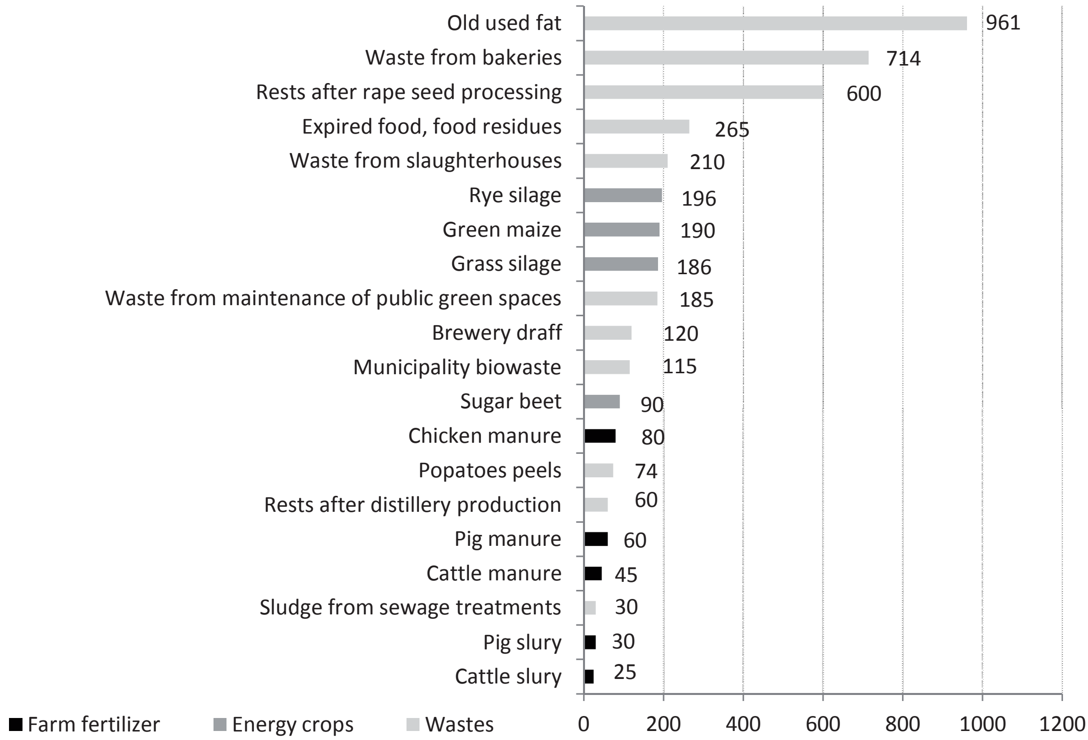

Figure 6 Biogas yield from one ton of fresh biomass (m3 / ton). Source: Banks et al. (2006), own processing.

was recorded in the last 8 years. It is obvious that larger share of corn maize harvests (from sowing areas of 215 thousand of hectares in 2013) is used as input material for agricultural anaerobic digestion plants. If we take into account the decrease in cattle breeding over the studied period (see Table 3), it can be stressed that a dynamic shift in using this crop has been recently experienced. Regional projections regarding extents of corn maize sowing areas started to be more differentiated than they were before the boom of anaerobic digestion sector. In regions with dynamic increase in numbers of anaerobic digestion plants (Vysočina, South Bohemia, Plzeňský, Královehradecký a Pardubický regions) the sowing areas of corn maize extended by 1-2%, whereas in regions without anaerobic digestion plants and with declines of animal husbandry the sowing areas are limited (Ústecký Region). As further increase in numbers of agricultural anaerobic digestion plant is planned in near future in the Czech Republic, further increase of sowing areas of corn maize is expected.

Declines in numbers of animal husbandry and changes of their breeding intensities are shown in Table 3. While use of agricultural crops as material inputs for energy production in anaerobic digestion plant is partially perceived as controversial issue by public, re-use of wastes after animal husbandry does not cause any important conflicts. On the contrary, the farmers believe that processing of slurry and manure for energy purposes, which would otherwise stay unused, is a good concept. As stated above, decisions of farmers to invest money for development of agricultural anaerobic digestion plant is closely connected to the necessity to secure the inflow of supplies necessary for long-term smooth operation of such facility. Thus farming of all types of animal husbandry provides potential for synergetic use within farm both for meat or milk production and for manure and slurry for anaerobic digestion plant.

As is clearly seen in the Table 3 in which changes of intensities of pig breeding in regions of the Czech

Republic are analysed, a dramatic decrease in pig breeding has been recently experienced. In certain regions it is more than a three-fifths decline (South Moravian, Olomoucký, Královehradecký, South Bohemia regions). Concerning the very low prices of pork meat that do not meet production costs and massive cheap imports of this commodity at the same time, further downsizing of pig breeding is expected. A question then arises if such enormous declines in animal husbandry breeding will not cause a shortage of material inputs for agricultural anaerobic digestion plants in near future with no further increase of sowing areas of corn maize for energy purposes.

CONCLUSION

The further increase in numbers of agricultural anaerobic digestion plants sector by 2020 is expected in the rural areas of the Czech Republic. It can be assumed that installed capacities of such facilities will increase by 15% (to 417 MW) and the number of plants will probably exceed 550 by the end of the decade. It is indisputable that all types of anaerobic digestion plants cause economic, social and environmental consequences . Such consequences are usually expressed spatially, which is most obvious within municipality where such facility is located. Although facilities for generation of renewable energies undoubtedly represent positive contribution for at least partial energy self-sufficiency of rural areas, they might cause controversies too (e.g. Van der Horst, 2009, Frantál and Kučera, 2009 or Frantál and Kunc 2010, 2011). Such consequences might be both positive (increase in jobs in municipality, increase and stabilisation of farmers income, re-use of agricultural waste, suitable processing of useless grass and hay, potential for processing of households bio-waste, reduction of dependency on fossil fuels, use of digestate as fertilizer of great quality, potential use of waste heat, reduction of CO2 emissions, etc.) and negative (controversial use of agricultural crops for energy purposes, dependence on subventions, increase of administrative load, bad impact on quality of life in municipality – potentially increased smell and traffic in municipality, potential reduction of attractiveness of municipality for tourists, etc.). It is obvious that the relevance of positive and negative consequences of anaerobic digestion plants operation can change over time. Various consequences with various intensities might be perceived differently before or during the construction of such facility, and possibly over the whole life cycle of its operation, when benefits should be apparent as well (e.g. cheap heat supplies). Some aspects, like farming of energy crops in formerly abandoned agricultural land, might be perceived negatively by some people, whereas there might be people who accept this approach as a positive contribution. A similar statement can be stressed while discussing food / non-food use of agricultural land or controversies connected to state supporting of renewable energies.

The most decisive factor that influences the development of agricultural anaerobic digestion sector seems to be subvention policy at national and European level. It is possible to get a subvention for both the construction and operation of such facility in form of state guaranteed purchase of electricity generated. By means of state incentives suitable size structure and spatial distribution of such plants might be achieved and thus be the most effective for purposes of rural development. Contemporary adjustment of national subvention policies seems to support this sector by way of improving incomes of farmers, whereas social and environmental problems are not taken into account seriously enough. What is left for discussion are potential links between subventions and the necessity to use more waste heat, regulating types of materials used as inputs, support of re-use of agricultural waste and reduction in the use of corn maize for energy purposes. Nevertheless, the largest potential can be generally seen in the processing of household's bio-waste, whose energetic importance is still underrated in these days (cf. Hlaváček et al., 2012).

Several points emerge from the analyses performed in this study that deserve to be highlighted. Agricultural anaerobic digestion plants have recently become an important alternative for accommodation of important part of agricultural production in the Czech Republic, which causes certain controversies. While the importance of corn maize planting as a basic material input for such facilities is constantly growing, recent decline of animal husbandry (mainly pig breeding) causes potential problems for the future (number of pigs heads declined to 50% of state in 2004). Energy reuse of wastes after animal husbandry (manure, slurry) do not raises debate on ethics like it is in case of agricultural crops planted for energy production. Contemporary spatial shifts in agricultural sector of the Czech Republic tend to follow spatial distribution of agricultural anaerobic digestion plants (this is particularly apparent in the belt of areas from the South Bohemia across the Českomoravská vrchovina Highland to the north up to the wider foothills of the Orlické hory Mts. or foothills of the Šumava Mts. and Plzeňský Region in western Bohemia).

At the first sight, the coexistence of agricultural anaerobic digestion plants and agricultural sector seems to be mutually advantageous. Agriculture, which is constantly looking for a way how to sell its agricultural production on market that is overfed by cheap agricultural imports in the Czech Republic, partially finds it in agricultural anaerobic digestion plants. Such facilities are supported by subventions as a form of improvement of farmer's income which enables them to run other, not so profitable agricultural activities (pig breeding, etc.). But it has to be stated that the above mentioned mutual advantageousness has its weak points. Although the use of agricultural land for non-food purposes raises public controversies, the use and processing of agricultural and nearby household's bio-wastes seems to provide much more benefits for environment, society and generally rural development. This indisputable potential is still waiting to get a larger attention of decision makers, farmers and wide public, too.

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Résumé

Prostorové souvislosti produkce bioplynu a proměn zemědělství České republiky po vstupu do EU: vzájemná symbióza, koexistence, či parazitismus?

Obnovitelné zdroje energie a jejich podpora je v České republice široce diskutovaným tématem, které budí emoce na škále od souhlasu až po naprosté odmítání. Nicméně právě podpora z národních i evropských zdrojů je faktorem, který nejvýznamněji ovlivnil dynamický rozvoj tohoto sektoru v poslední dekádě. Bioplynové stanice jsou jednou z variant zařízení na výrobu obnovitelných zdrojů energie, která vedle solárních elektráren zaznamenala v posledních letech nejvýznamnější růst svých kapacit. Předkládaný příspěvek si klade za cíl nejprve analyzovat samotný fenomén bioplynových stanic, jeho legislativní, strategickou podporu, podpůrné finanční nástroje, jednotlivé typy stanic a dále analyzovat na základě dostupných statistických dat prostorové rozmístění jednoho z jejich typů, a to zemědělských bioplynových stanic. Na základě srovnání dat o bioplynu a dat o zemědělské výrobě jsou vyvozovány základní konsekvence mezi propady zemědělské výroby v regionech České republiky a nárůsty počtů a instalovaných výkonů zemědělských bioplynových stanic. Krátce je rovněž analyzována struktura osevních ploch a intenzita chovů hospodářských zvířat a jejich souvislosti s rozmístěním zemědělských bioplynových stanic. Lze konstatovat, že zemědělské bioplynové stanice mají stále rostoucí vliv na strukturu osevních ploch zemědělství České republiky a jsou veřejností i samotnými zemědělci více považovány za alternativní zdroj příjmů než příspěvek k ochraně životního prostředí, omezení produkce skleníkových plynů a změně klimatu.

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