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Community tensions, participation, and local development: Factors affecting the spatial embeddedness of anaerobic digestion in Poland and the Czech Republic

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Abstract

AD plants are an important part of energy transition towards low-carbon rural economies in Central European countries. However, their benefits in making rural spaces more energy sustainable and energy self-sufficient are frequently questioned. In our paper, we strive to deepen our understanding of the level of embeddedness of two modes of operation of AD plants (AD on-farm, AD off-farm) in cases of Poland and the Czech Republic. We evaluate the pros and cons of both modes and assess their importance for the local rural development and energy transition through the lens of their embeddedness in the life of rural communities. Through questionnaire surveys in two municipalities (Buczek in Poland, Stonava in the Czech Republic, n=232) and a set of expert interviews (19) with local and regional stakeholders, we have found that AD plants are specific rural enterprises as they usually rely on local biomass resources and are generally more grounded in the local economy and in local social structures than other enterprises. We also discovered that both types of AD plants investigated create significant (but varied) linkages with local stakeholders. The awareness of ADs among local population is high and significantly influenced by previous visits to the AD plant. By

providing jobs and organizing local events for the local population operators of AD plants create space for their deeper acceptability and their embeddedness into the life of rural communities, however, site-specificity and local socio-cultural contexts must be also considered.

Key words: embeddedness, rural energy transition, biogas energy, local development.

Highlights

- Embeddedness of anaerobic digestion plants in the life of rural communities is surveyed.
- Questionnaire surveys and a set of interviews with stakeholders were conducted.
- AD plants have the specific qualities of being grounded in local economies and relying on local resources.
- Visiting an AD plant significantly (and positively) affects the opinion of local publics about AD.

1. Introduction

There is no doubt that renewable energy plays a crucial role in the contemporary energy transition of European rural areas. We are already aware of potential social, economic and environmental benefits that are connected to decentralized systems of renewable energy generation. What we also know is that the impact of a particular renewable energy system on host communities might oscillate between a very well-developed contributions towards local development on the one hand and very bad consequences on the other hand. In reality, the relations between the RE systems and local development are much more complicated as they are also the focus of subjective preferences of individuals that change over time and place. Generally speaking, multiple factors contribute to the level of local acceptance (or non-acceptance) of renewable energy systems.

In our study, we focus on biogas as one particular type of renewable energy and on the embeddedness of anaerobic digestion plants (AD plants), as facilities where biogas is produced, in the life of the population of host communities. We are interested in AD plants as a tool that has the potential to create energy from bio-waste (from agriculture, food industry or households) that would be otherwise left unused. Ideally, AD plants should be organized to

be in line with local community needs concerning the size, type and structure of input materials (process bio-waste from given community), output material (supplies of heat for the local community, local usage of biogas) or socio-economic benefits (jobs for local people). Similarly, the energy and economic outputs of AD should be organized more wisely to match the settings of local communities to support their embeddedness in the life of the local community. Such alignment may not happen, however, and AD plants can also affect the hosting community negatively as well (through an increased level of traffic, odour pollution, etc.). In other words, there is a significant scope for embeddedness (or disembeddedness) of the AD in the local society.

Geographically, our study is located in two Central European countries (Poland and the Czech Republic) where the usual strategies of investors regarding the location of a new AD plant and its operation differ significantly. In Poland, AD plants are usually located and operated separately from agricultural farms, while in the Czech Republic farmers are the most frequent operators of AD plants and these are then located within the area of their agricultural operation. In both cases, we are particularly interested in plants based on the energy processing of agricultural crops and agri-food wastes, as the most frequent type of AD plants in both countries.

Thus, the aim of our paper is to evaluate the operation of two modes of AD plants through the lens of their embeddedness into the life of rural communities. Our main research question lies in the search for differences in the level of embeddedness of AD plants into the life of rural communities when operated in various business models. Our endeavour is also to explore how various levels of embeddedness impact rural energy transition in both countries.

In the first part of the paper, we frame our research within the wider field of embeddedness studies and try to understand the particularities of energy transition in the rural conditions. The second part is devoted to analyses of the level of embeddedness for selected AD plants in Poland and the Czech Republic. Finally, we formulate recommendations concerning the consequences of the rural energy change and AD sectors for both countries.

2. Theoretical framework

2.1. Embeddedness concept

The operation of enterprises in a given area may, and generally has to, result in ascertain level of integration with the given territory and with socio-economic processes that

are evolving there. This connection is expressed through a creation of varied and multifaceted relations with local institutional and socio-economic environments that include local authorities, local leaders, the local community, and other enterprises (Kalantaridis and Bika, 2006). This assumption makes enterprises an integral part of socio-economic relations, the role of which should not be solely based on profit-making but also on utilizing local natural, social or economic capital, and their operation shall resonate and contribute to local development needs of the given territory.

These relations created by the enterprise, as well as the relational resources (see Lester, 2013), are deemed to create a significant source of competitive advantage of particular regions, and might be understood in terms of the (level of) embeddedness of the enterprise in the local environment (Meyer et al., 2011). Thus, the embeddedness might be seen as both a natural attribute and a result of the specific economic activity of humans in the territory (Zukin and DiMaggio, 1990), which is related to the nature, depth and degree of association of a particular entity with surrounding social and economic environment (Uzzi, 1996, 1997).

From an historical perspective, the concept of embeddedness is rooted in the research of Karl Polanyi (1994) that was published in his famous book Great Transformation (firstly published in 1944). Polanyi argued that the economy is immersed in social relations; thus, every economic activity is in a way determined by social, cultural and political factors. Polanyi also defined the opposite term to embeddedness - disembeddedness. He argued that disembeddedness (as a system that is solely governed by supply and demand and by no off-economic powers) leaves the society at the mercy of self-regulating market (Cardoso Machado, 2011) and it stands apart from the rest of society. These conclusions lay the foundations for the development of the concept of social embeddedness, created by Mark Granovetter. According to Granovetter (1985), embeddedness as a concept is rooted in sociology and generally defined as the idea that companies are connected by networks of personal relationships, and their economic behaviour is closely embedded in networks of interpersonal relationships (Granovetter 1985). In other words, embeddedness is a state of being located (or secured) within a larger entity or context or the territory. Granovetter (1985) also assumes that every economic activity is embedded in specific, currently functioning systems of social relations. This notion concerning the significance of temporal and contextual aspects of embeddedness (Gnyawali and Madhavan, 2001) seems to be of a crucial importance as it implies that the researched problem is of a site-specific nature. On the other hand, we already know that an increased level of embeddedness of local companies positively influences local development (Cooke et al., 2005 or Ramesh and Gelfand, 2010).

Although the very idea of embeddedness is visibly significant, it has not been unequivocally understood and defined so far. As a matter of fact, it is often seen as a feature of the economic activity of humans (Zukin and DiMaggio, 1990) or as an expression of nature, depth and level of a given company´s bond with its environment (Uzzi, 1996, 1997). The diverse perception of embeddedness brings about different typologies of the notion. One of the most capacious typologies points to the existence of four basic types of embeddedness: cognitive, cultural, political and structural (Zukin and DiMaggio, 1990). Halinen and Törnroos (1998), on the other hand, distinguish between temporal, spatial, social, political, market, and technological embeddedness, while Brinton andKariya (1998) define a distinct institutional type of embeddedness.

Alongside the above-mentioned types, a pivotal role in terms of generating developmental impulses that translate to an impact on the local development is played by territorial or spatial embeddedness and its subtype, local embeddedness (Stryjakiewicz, 2001; Domański, 2004; Stachowiak, 2011). Thus, the enterprise is territorially embedded in its particular social and cultural relationships that might be measured by in-place-specific characteristics, infrastructure, operating environments, or, production conditions. As Granovetter (1985) or Uzzi (1996) propose, local embedding means matching of practices, routines, and (or) resources that might be characterized as specific to certain standards for a given location.

Due to the fact that embeddedness of enterprises in the local environment might improve access to local resources (Ratajczak-Mrozek, 2009; 2014), it is paramount to their operation (Dacin et al., 1999; Thornton, 1999) and is particularly important in the case of newly-created, innovative enterprises established in rural areas. The success of those entities is grounded in the development of cooperation (Bengtsson and Kock, 2000) (both formal and informal or general and individual) on different levels: i) business to business (B2B), ii) business to administration (B2A), and, iii) business to consumer (B2C). This cooperation comprises relations with different actors of the economic game, relations between resources held by actors and actions performed by actors using the resources in a given area (Stryjakiewicz, 2001; Hagedoorn, 2006).

Overall, there is much consensus that business activity is influenced by the level of embeddedness of an enterprise in a specific local context (Thornton, 1999). This state of being embedded we understand as being placed in a context that facilitates and hampers the actions of actors in a particular territory (Thornton, 1999; Zahra, 2007). As we are aware that too few contextual studies on embeddedness of rural enterprises exist, as signalled for

instance by Welter (2011), Zahra (2007), Korsgaard and Anderson (2011) or Korsgaard et al. (2015), we have conducted a research focused on the level of embeddedness in case of AD plants as a rural enterprise. Embeddedness in rural areas is a different process from that in urban areas. These differences are particularly visible in case of rural Central Europe. This stems from specific features of socio-economic structures characteristic of rural areas, including primarily traditional social resources based on family and neighbourhood ties (Frazier and Niehm, 2004) as well as the role of homogeneity - there is a high degree of overlap among different social roles that local people carry out (Francis et al., 1990; Gülümser et al., 2009). Therefore, the success of enterprises operating in rural areas requires: building relations with the local community, gaining the acceptance of the rural community for new businesses, involving the local people in the operation of the businesses, and involving entrepreneurs in local social relations. Another factor of importance here is perception. A positive reception of a given entity may build public support upholding the activities of an enterprise in a given area. On the other hand, the lack of trust and a critical reception may result in the local community disapproving of the businesses' operations and perceiving the companies as the only beneficiaries of the investments (Granovetter, 1985; Francis et al., 1990; Roberts, 2002; Del Rio and Burguillo, 2008). This, in turn, may lead to a situation where the benefits resulting from the presence of an enterprise (here: biogas plants) in a rural area are asymmetrical and unevenly distributed.

The leading idea of the paper is that local context and spatial relationships are centrally related to embeddedness. Here we follow the conclusion of Hess (2004), that all types of embeddedness have spatial dimension. The study concerns biogas plants as the functioning of these enterprises hinges on spatial and social relations marked by regional, and more importantly, local ties. As the first business-oriented AD plants were established in the Czech Republic in 2002, and three years later in Poland (Chodkowska-Miszczuk et al., 2017), they are still perceived as a novelty in the countryside. Together with the fact that their operation in agri-energy sector is characterised by significant overlaps to social and environmental spheres of the rural areas, our research contributes to the revelation of barriers that obstruct a more suitable use of AD plants for the needs of local development.

2.2. Rural energy transition

Over the last decade, many countries have started the transition towards more sustainable energy systems (Lund, 2007), including renewable energy development,

especially in rural areas (Martinat et al., 2016). There is no doubt that this offers wide possibilities for functional diversification of agricultural activities (Del Rio and Burguillo, 2009) and it might lead to the desired and more sustainable socio-economic and environmental development of the rural areas. AD plants and renewable energy in the countryside, in general, are becoming an integral part of the wider societal change in favour of the sustainability transformation of the rural (Kitchen and Marsden, 2011, Marsden and Rucinska, 2019). We must keep in mind that the primary purpose of agricultural activities is food production (Ericksen, 2008), on the other hand, the connection of agriculture to renewable energy production seems to be mutually beneficial (Pretty, 2008) - if wisely managed. Purpose grown energy crops (like maize), but primarily agricultural waste, is usually processed in AD plants for biogas as renewable energy that is transformed into electricity and heat (Chodkowska-Miszczuk and Szymańska, 2013). Such prospective benefits may be highly conditions. Much depends on the scope to adapt the location of AD, its size and the structure of input material for AD to local context, so that the smooth long-term operation of AD is ensured, or whether any spatial fixes are accompanied with benefits for local community and minimization of side effects (odour, increase of traffic etc.). The huge potential of such locally generated electricity and heat for local development is obvious and plenty of successful examples of such symbiosis exist (Frantál et al., 2018).

AD plants are also distinctive to many other renewable energy technologies, because their energy-generating capacity is more predictable. We know that biogas energy production is not subject weather-related intermittency in the same way as wind, water or solar power plants. Control over the structure of material that is energy processed in AD plants also enables them to significantly affect waste management of particular farms towards more sustainable solutions (Holm-Nielsen et al, 2009).

Embeddedness concerns also matter because AD plants are established and operated largely as a result of political, economic and social determinants (Bluemling et al., 2013; Wirth et al., 2013). Thus, the local context needs to be taken into account to ensure that they function effectively and according to the needs of local community. This necessitates research concerning the embeddedness of these enterprises in the local environment and the significance of this process for the success of the rural energy transition.

There are policy challenges too, where reconsideration of the settings of energy support systems is needed to be in line with specificities of rural areas. Such support should include measures that support building relations of businesses with the main local stakeholders, such as inhabitants, local authorities, other enterprises and various institutions.

As rural areas are characterised by lower population density, it seems beneficial to support a de-centralized system of generating renewable energy in the countryside. Moreover, the size of individual AD plants really matters as the amount of potential waste that farms in their proximity are able to generate. On the other hand, this raises the question concerning future agricultural changes that will be significantly affected by ongoing climate change (Rose et al., 2014). To make the primary focus of AD the energy processing of agricultural waste instead of processing purpose-grown energy crops is driven by obvious environmental benefits in processing of waste that would be otherwise left unused. In reality, balance between utilisation of energy crops and waste is most frequently business decision as a result of logistics of supplies and stable energy efficiency of generated biogas.

In order to fully analyze the issue of embeddedness of an agricultural AD plant in the local environment, it is necessary to include social and spatial relations in a given area as they determine all decisions in the scope of production, distribution, and consumption of energy. The legal arrangements regarding the energy sector applicable in a given area have to be also analyzed to identify the key particularities. Careful attention has to be devoted to studying the value systems influencing the daily behaviour of the population of the local communities. Last but not least, the perception of usage of the surrounding landscape by the local population has to be significantly taken into account.

To move forward the public and political support for individual energy industries need to be reconsidered (Bouzarovski, Bassin, 2011). In-depth analyses are particularly needed in regions whose development is determined by a complicated historical-political past related to the communist economy that still significantly deforms contemporary social and economic relations. Currently, this might be, for example, expressed by the dominance of one energy source in the structure of national energy production (e.g. hard coal in Poland, lignite in the Czech Republic), as well as energy centralization and energy dependence on Russia (Kats, 1991; Buzar, 2007) that is also closely linked to the development of nuclear energy in Central Europe. This common history shapes the scope and pace of socio-economic changes in rural areas (Bański, 2008), encompassing also the energy sector. Therefore, a need to identify the drivers of energy transition in rural areas arises.

3. Methodology

3.1. Selection of sites for the research

When tackling the main issue of the paper, i.e. whether and how the level of embeddedness contributes to the energy transition of rural areas, the authors referred to the examples of two types of AD plants that occur in Central European countries. Case studies from Poland and the Czech Republic were selected for the study as these countries are characterized by a similar historical and political past related to the communist economy in force in the former Eastern Bloc countries. To meet obligations to the European Commission (e.g. Directive 2009/28/EC) the AD sector in both countries has developed significantly. Currently, more than 550 AD plants with a total installed capacity of 363MW are found in the Czech Republic; in Poland AD development is slower, but almost 100 AD plants are located there with an installed capacity of 102 MW). The year 2002 witnessed the launch of production of biogas energy from biogas AD stations. The Czech Republic belongs to one of the European leaders in terms of the number of AD plants. As a result of the current system solutions enabling financial support from the state budget for biogas investments, over ten years the number of agricultural AD plants in the Czech Republic increased to almost 400 (Martinat et al., 2013). In 2015, the share of renewable energy coming from biogas energy in the Czech Republic was 25% (Tab. 1). Most agricultural AD plants are located in the north-south belt in the central parts of the country, primarily in sub-montane natural conditions.

In 2011, there were eight agricultural AD plants in Poland and over the next six years this number increased 12-fold, so that at the end of 2017 it amounted to 96 plants. Financial resources available from European Union funds have generated significant impulses for the creation of AD plants (Chodkowska-Miszczuk et al., 2016). The largest number of AD plants have been built in north-western and western Poland. See basic comparison of AD sector in the Czech Republic and Poland in Table 1.

Table 1

Selected indexes characterizing the AD plants in the Czech Republic and Poland, 2018

	Czech Republic	**Poland**
Total number of AD plants	**574**	**303**
Total number of agricultural AD plants	**390**	**96**
The share of biogas in the production of electricity from renewables (%)	25.0	4.7
Total installed capacity of AD plants (MW)	363	102
The average installed capacity per one AD plant (MW)	0.9	1

Sources: own survey based on data from: http://www.kowr.gov.pl/odnawialne-zrodla-energii/biogaz-rolniczy/wytworcy-biogazu-rolniczego (15.11.2018) https://www.eru.cz/en/elektrina.(26.10.2018)

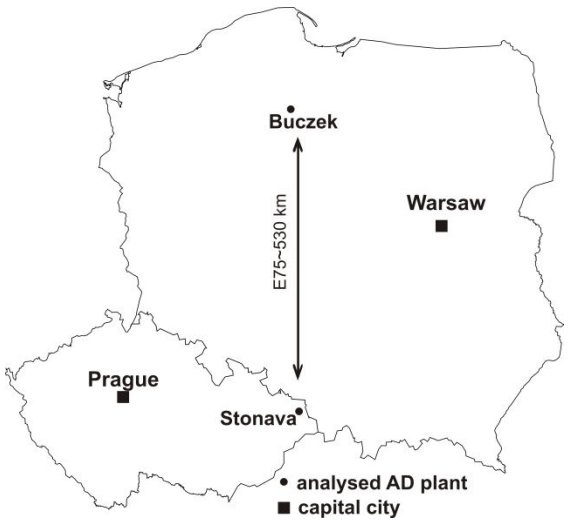
Detailed studies tackled AD plants employing different modes of functioning so that various perspectives of both types of AD plants could be defined (see Strauss and Corbin, 1990). For our study, we have been working with two types of operation: an AD plant operating off-farm, and an AD plant operating in on-farm mode. Importantly for our analysis, each type may embody different bundles of embeddedness dimensions.

(i) AD plant in Buczek (Poland, Kujawsko-Pomorskie Region, Świecie county, Jeżewo commune), as an example of a stand-alone entity – an off-farm biogas plant;

(ii) AD plant in Stonava (the Czech Republic, Moravian-Silesian Region, Karviná county, Stonava commune), as an example of an entity with functional ties with Stonava Farm, an agricultural company located in the same place – an on-farm biogas plant (Table 2).

Table2

Basic features of surveyed AD plants

Location of analysed AD plants	Details of analysed AD plants
	(i) Buczek AD plant (PL) - Biogas off-farm It is located in the natural protected area - Natura 2000 (bird areas – PLB 220009 Bory Tucholskie, Geoserwis of the General Directorate for Environmental Protection). It is a separate entity, not connected to local farms. The AD plant is an external investment of a company from a near by city, The AD plant operates from 2014. Total installed capacity is 1.8 MW. The biogas is produced from the waste of agri-food production and maize silage (the input material is supplied by external suppliers).
	(ii) Stonava AD plant (CZ) - Biogas on-farm Stonava communehas been affected by mining (four coal mines in the neighbourhoods). The AD plant as an integral part of an existing agricultural farm named Stonava Farm; the internal/local investor. The AD plant operates from 2009. Total installed capacity is 1.4 MW. The biogas is produced from maize silage and waste from agricultural production (input material from own farm).

Source: Own survey.

The AD plants selected for further analysis are notable for the level of innovation in the agricultural biogas production technologies they apply. They are also remarkable by their specific locations. The Buczek AD plant (in Poland) lies within a Natura 2000 legally protected area. On the other hand, the Stonava AD plant (Czech Republic) is located in the

only area of hard coal mining (Martinat and Turečková, 2016) in the territory of the Czech Republic and in the vicinity (less than 10 km) of a city of Karviná (population 54 thousand in 2018). Both AD plants are conveniently located within the transport network, including the E75 European route which is approximately 25 km from both localities (as shown in Table 2).

3.2. The procedure and conceptual framework

Therefore, the aim of this study is to identify whether AD plants operating in the two modes are embedded in the local context (i.e. they are rural entities), or whether they are disembedded from local structures (i.e. they are entities operating in rural areas). To this end, we have considered the mechanism of the process of their embeddedness in three aspects: alliance, awareness, and assessment. The issue of embeddedness refers to the new rural development paradigm (Van der Ploeg et al., 2000; Woods, 2011) highlighting the importance of a contextual approach based on local narration. As specific indicators of embeddedness we point to the alliances between AD plants and local entities, which are the basis for shaping awareness, and assessment. Relationships built with a collection of heterogeneous local entities provide access to knowledge, the understanding of local rules and conditions, expectations of local communities, as well as help build the reputation of the enterprise and gain trust (Ettilinger, 2003).

In order to achieve the above-mentioned aim, we should address the following questions regarding the alliance, awareness, and assessment of the operation of AD plants in two modes (Fig. 1.):

(1) Are AD plants (two modes of operation of AD plants) rural enterprises or rather enterprises in rural areas in the context of the assumed business model, including methods of obtaining substrates, using the plants´ products, and cooperating with local entities—other enterprises, institutions, the local society?

(2) Does cooperation with local actors, indicative of the embeddedness of AD plants in the local environment, impact the awareness of the local population regarding the local AD plants?

(3) What are the pros and cons of the operation of AD plants in two modes, when viewed through the lens of the embeddedness concept?

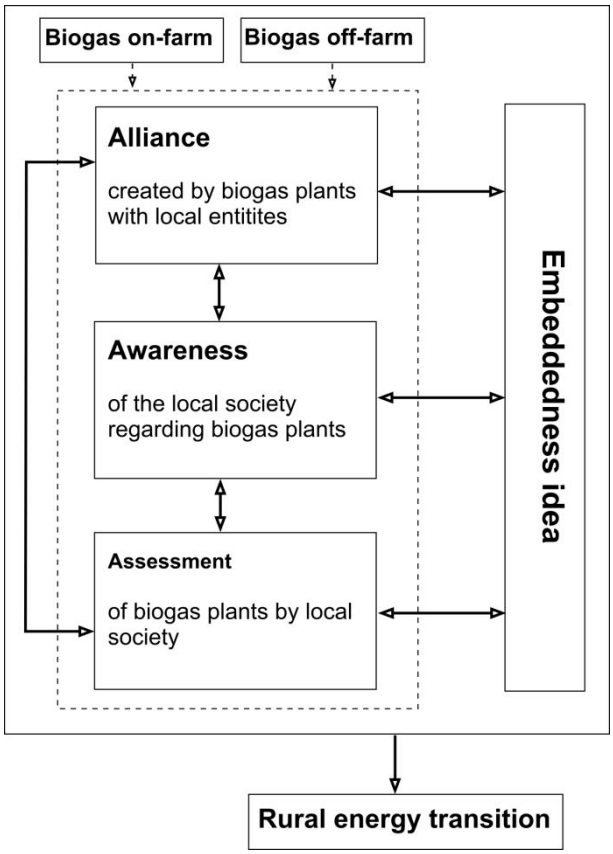


Fig. 1. Conceptual framework
Source: Own survey.

3.3. Research methods and data

In order to reach the research objective, the authors had to apply methods enabling them to collect information directly from persons interested in the operation of AD plants, including residents of the studied areas, representatives of local public institutions, other entrepreneurs and local leaders. We, therefore, used case studies and comparative methods which allowed us to distinguish and characterize the features of the analyzed entities representing two types of AD plants. We applied a two-stage research procedure combining quantitative and qualitative approaches (Miles and Huberman, 1994).

The first phase of the research comprised a quantitative study in the form of a survey administered to a non-random sample. The non-probabilistic sample was based on the principle of accessibility. The survey form comprised of several sets of closed-ended questions organised in the form of a matrix. Open-ended questions also had a considerable role to play in the questionnaire, albeit their number was deliberately limited. The survey

form centred around three axes: (i) knowledge of AD plants; (ii) relations initiated and developed by AD plants; (iii) the local community's perception of AD plants.

The survey with the inhabitants of two communities was carried out between September and October 2017. A pre-test of the questionnaire to ensure the validity and intelligibility of individual questions had been conducted on the sample of the local population in August 2017. A total of 232 respondents aged over eighteen participated in the survey (Table 3).

Table 3

Overview of the structure of respondents

		Stonava (CZ)	Buczek (PL)
Gender	Female	64%	61%
	Male	36%	39%
Age	18-24 years	2%	5%
	25-34 years	28%	17%
	35-44 years	58%	18%
	45-64 years	11%	56%
	65 years and more	1%	5%
Education level	Primary	6%	5%
	Vocational	27%	20%
	Secondary	47%	35%
	Tertiary	20%	40%
Length of residence	Less than one year	3%	2%
	1-5 years	18%	8%
	6-10 years	22%	2%
	More than 10 years but no since birth	32%	42%
	Since birth	25%	47%

Source: Own survey. Number of respondents in Buczek (PL) was 106, in Stonava (CZ) 126.

The collected data was deemed reliable and fully reflecting the knowledge of the studied areas. This was verified during qualitative studies carried out in the second phase in the form of semi-structured face-to-face interviews with the local stakeholders. The choice of respondents was intentional and based on the assumption that they represented the different spheres of the socio-economic life, including the political and the social, while at the same time having a good working knowledge of the issues related to the operation of AD enterprises. It should be noted here that the determining factor was the respondents' comfort during the interviews, which were one-off events taking place at work and conducted in line with an adopted procedure. An interview would take 1–1.5 hour. At the respondent's consent interviews were recorded and transcribed. The total number of interviews reached 19 and the respondents were divided into two groups: (i) owners/managers of AD plants and the farm

with which the AD plant holds functional ties; (ii) other local entities, such as the local authorities, other entrepreneurs, NGOs, local leaders, residents (Table 4).The division of the respondents into two groups results from the different roles in the social structure played by their members. The owners and managers of biogas plants primarily represent the interests of the embedded enterprises, while local entities – local decision-makers - represent the local context.

Table 4

Overview of interviewees

Interviewees	Gender	Date of interview	Type of respondent	Place
1	M	02/09/2017	Biogas plant	PL
2	F	07/09/2017	NGOs	PL
3	F	07/09/2017	Public sphere local	PL
4	F	21/09/2017	Public sphere local	PL
5	M	21/09/2017	Public sphere local	PL
6	M	21/09/2017	Public sphere local	PL
7	M	26/09/2017	Private sphere regional	PL
8	F	26/09/2017	Public sphere local	PL
9	M	02/10/2017	Private sphere regional	PL
10	M	02/10/2017	Private sphere local	PL
11	M	02/10/2017	Private sphere local	PL
12	M	18/10/2017	Biogas plant	CZ
13	F	19/10/2017	Public sphere regional	CZ
14	M	19/10/2017	Public sphere regional	CZ
15	M	20/10/2017	Public sphere local	CZ
16	F	27/10/2017	NGOs	PL
17	M	27/10/2017	NGOs	PL
18	M	18/10/2017	Biogas plant	PL
19	F	19/10/2017	Public sphere regional	PL

Explanation: interviewees are anonymized on purpose
Source: Own survey; n=19.

The material obtained in surveys was analysed using SPSS software (creation of the database, and identification of the relationship between analysed variables). In-depth qualitative interviews were analysed and used as background information.

3.4. Methodological limitations

The present research is characterized by certain limitations stemming from the reference to case studies, which qualifies the opportunities to generalize. The local context is pivotal in the operation of AD plants as innovative energy enterprises. Therefore, the process of embeddedness of AD companies in various locations may differ from case to case.

Nevertheless, the conclusions which arise from the study help solve the research problem raised in this paper and expand the conceptual framework.

4. Research results

4.1. Relations and alliances created by AD plants

The assessment of the embeddedness of the two AD plant model case studies starts with an analysis of relations developed by AD enterprises with local entities, determining the process whereby enterprises are embedded in the local environment. The analysis of links created by AD enterprises helps indicate whether they are rural enterprises or rather primarily enterprises operating in rural areas. The study considered interactions developed with local enterprises, institutions, non-governmental organisations as well as with the representatives of the local society. Regardless of the kind of business model applied, both AD plant types create linkages with a diverse set of entities. In cases of both types, most answers to the question "*Does the AD plant cooperate with…"* regarded cooperation with farmers. When comparing the results, it is clear that in the case of an AD off-farm mode, the share of answers in the affirmative to the question of cooperation with farmers was high (55.7%) as in the biogas on-farm mode (41%). The local authorities are the second most prevalent co-operator of AD plants, with 45.2% and 32% of indications, respectively (Fig. 2). The pivotal role of relations with the local authorities—but also their stability—as a precondition for the success of AD business operation is emphasised by one of the respondents in the interviews: "*Relations with the local environment depend on the relations with local authorities. As long as these relations are good, you can develop new projects, e.g. concerning the use of heat. Personal matters are of an extreme importance as the mayor changes every four years and when a new force comes to power you have to build relations with the authorities all over again"*[I13].

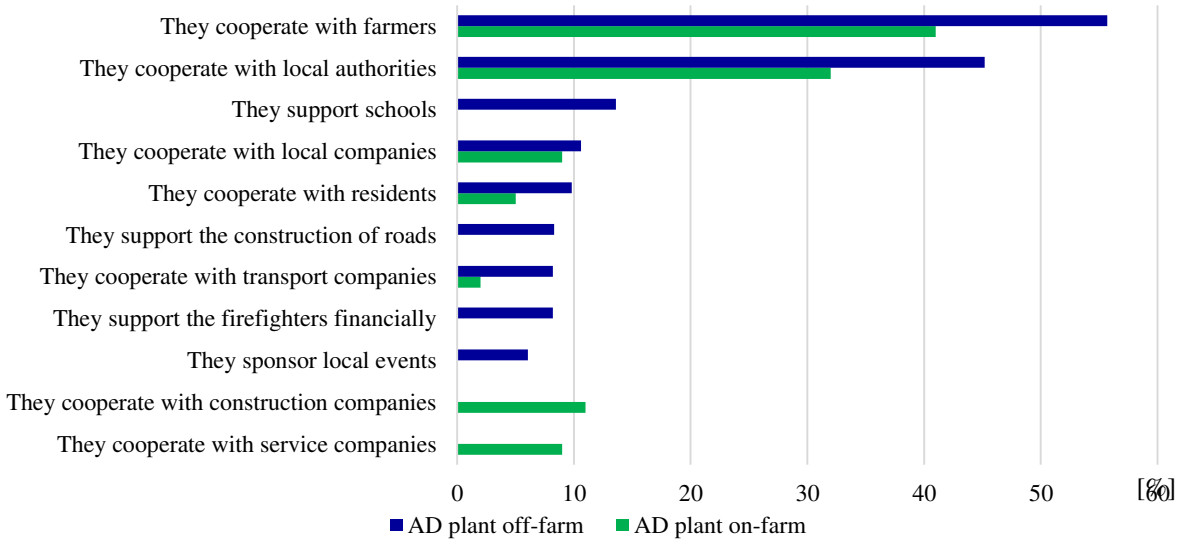


Fig. 2. The distribution of answers to the question: *„Does the AD plant cooperate with…?"* Source: Own survey.

The analysed AD plants also established cooperation with other local entities. In order to carry out its business operations effectively, the off-farm AD plant (in Buczek) needs to build relations in the supply chain: with feedstock suppliers, i.e. agri-food enterprises (local, regional, and supra-regional) on the one hand, and local farmers (recipients of the organic fertiliser based on digestate)—on the other. A local leader from Buczek is one of those noticing the creation of such a web of interrelations; he concludes: "*It [biogas station] most certainly cooperates with a large number of companies because the very number of transports that come here proves that. With the local farmers, surely, because the digestate is transported to the fields as fertilizer and I think the farmers take it gladly. Because I can see they are taking it"*[I10].Due to the fact that the on-farm AD plant model functions as an integral part of an agricultural enterprise that ensures the supply of substrates and the receipt of the digestate used as organic fertiliser, the effective operation of a biogas enterprise does not require building relations in the supply chain. The head of the AD plant in Stonava said: "*The substrates for the biogas plant come from the company's own farm (...). We don't buy any substrates. Sometimes we are approached by potential business partners who would like to sell their waste (...). For the stability of the biogas plant, I need to have some more of this waste"* [I12].

Enterprises also become embedded in the local environment through expanding and strengthening their contact with the inhabitants. Such links with the local society may be and

are enhanced through the employment of local residents. The head of the Buczek AD plant said: **"***A person from a neighbouring homestead works at the plant"* [I1] and the head of the Stonava AD plant added that *"three people from the area, from here, are employed on a permanent basis; during renovations, larger actions, additional people are employed"* [I12]. The results are by far similar because AD plants come to be identified not only as new enterprises but also as workplaces, including relatives and friends. At the same time, employees based in the local environment are regarded by AD plants' managers as loyal and devoted. As the manager of the AD plant in Buczek stressed: *"In the case of a failure, he may always intervene. You have to have allies in the local residents"* [I1].

Another opportunity to expand and deepen relations with the inhabitants lies in the involvement of the enterprises in activities improving the quality of life of the local community. Thus, the off-farm biogas plant (in Buczek) provides financial support to local institutions: schools, the voluntary fire service. It participates in undertakings that are important for the residents, including the organisation of cultural events and the construction and renovation of local roads. According to the words of another local entrepreneur from Buczek: *"For sure (...) the head of the biogas plant takes part in that [road renovation] because all entrepreneurs take part in something like that"* [I11].The on-farm biogas plant (in Stonava) also gets involved in initiatives organised with a view to the local community because as the Mayor of Stonava underlines: „*Companies that operate in Stonava, not only the farm, support public life (...). It is a small but nice and wholehearted help"* [I15]. Due to the fact that the on-farm biogas plant functions within the Stonava Farm agricultural enterprise, all actions taken for the benefit of the local community are supported by the agricultural enterprise. The most popular undertakings include participating in the organisation of local events, including primarily harvest festivals, the St. Hubert's feast, sporting events and all works covering the cleaning and renovation of public space where the local community meets and integrates. As the Mayor of Stonava remarks: "*As such, there is no cooperation with the biogas plant itself (except for the plan for supplying of heating to municipal buildings), but in general there is an exemplary cooperation with the farm"* [I15], it is confirmed by the AD plant owner: "*We cooperate with local residents, the authorities, organizations, not as a biogas plant but as a whole farm"* [I12]. Moreover, it was Stonava Farm that was listed by the respondents among companies that are chiefly involved in the local matters, while the AD plant was omitted (Fig. 3). The activities of Stonava Farm are noticed by people with different education levels, while the mining company (OKD) in the

second place was more frequently mentioned by persons with secondary and vocational education.

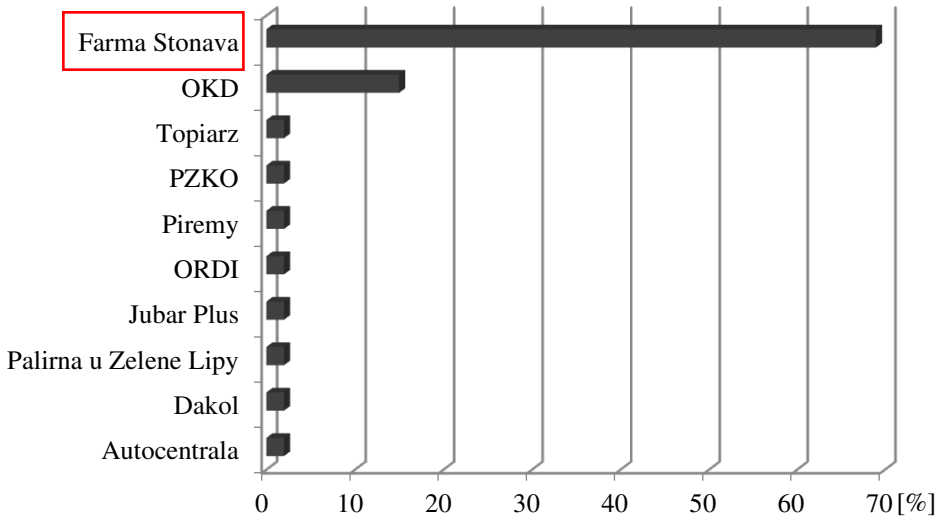


Fig. 3. The distribution of answers to the question: *"Please name the companies in the commune that support the inhabitants"*
Source: Own survey.

Identified relations are characterized by both dimensions: social and economic. The first one manifests in involving entrepreneurs in local social relations, social roles. The second one in supporting local events, co-financing of local services, etc., the employment of local residents, and cooperation regarding supply chain management.

4.2. Awareness of AD plants

The initiation and strengthening of interactions between the AD plants and the local society translate into the local residents' level of awareness about these innovative businesses. It is worth noting that the vast majority of respondents answered *Yes* to the question: *Do you know the AD plant [off-farm or on-farm biogas plant]?* In the case of the off-farm biogas plant, 74% of the answers were in the affirmative, and 68% for on-farm plants (Table 5). Persons with secondary and tertiary education prevail among those who confirmed to have heard of the AD plant, reaching 79.6% and 70.4% for the off-farm and on-farm biogas plants, respectively.

Table 5

The distribution of the answer *Yes, I have heard of it* to the question: *„Do you know the AD plant?"*

		AD plant off-farm	AD plant on-farm
Age	18-24 years	2.0 %	0.9 %
	25-34 years	20.4 %	25.2 %
	35-44 years	10.2%	58.6 %
	45-64 years	61.2 %	14.4 %
	65 years and more	6.1 %	0.9 %
Education level	Primary	2.0 %	3.7 %
	Vocational	18.4 %	25.9 %
	Secondary	38.8 %	52.8 %
	Tertiary	40.8 %	17.6 %

Source: Own survey.

Notably, only 9.1% of the surveyed people indicated the answer: *"I have never heard of it and I don't know the Buczek AD plant"* (off-farm). This number comprised women residing in the neighbourhood since birth and/or for over 10 years. At the same time, as many as 22.3% of the respondents confirmed that they had never heard of it and they did not know the Stonava (on-farm) AD plant (Fig. 4). Within this group, women residing in the neighbourhood for several years constitute 75.7%. When combined with the fact that local residents know the Stonava agricultural enterprise and its activities addressed to the local society, this information provokes a conclusion that the on-farm biogas plant in Stonava, being an integral part of the agricultural enterprise, is less often perceived as a separate company.

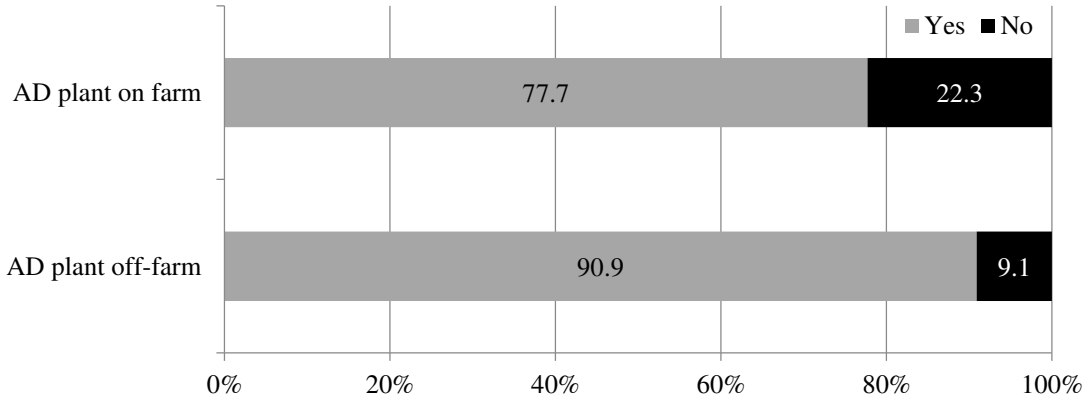


Fig. 4. The distribution of the answer for the question *„Have you ever heard of AD plant in your community and do you know it?".*
Source: Own survey.

Knowledge about the AD plant, especially knowledge obtained in free conversation with the plant's manager and staff members, translates into how it is perceived by the local community. A trip around the AD plant provides an opportunity to convey information and exchange observations. Those respondents who visited the plant not only gained and/or improved their knowledge about the production of energy from renewable sources, including biogas, but also learned about other activities undertaken by the AD plants, not directly related to the production process, but carried out with a view to the local community. Such activities comprise the support for the construction and modernisation of local roads and the cleaning of the same. The rise in local road traffic and the increased exploitation of existing road infrastructure are the costs resulting from business activity borne first and foremost by the local society. The above-mentioned activities, aimed at alleviating those burdens, can be read as an expression of corporate social responsibility.

The decision to visit the biogas plants (individually, or in a group) is taken by people interested in the issue of generating biogas, wanting to see new facilities, learn about the production process, but also verify stereotypes or the well-established message conveyed about biogas plants. Men are the predominant group of visitors to the biogas plants (70%), characterised by vocational, secondary and tertiary education, living there since birth and/or for over 10 years. At the outset of the off-farm biogas plant in Buczek, one of the local NGO organised a bike trip to the plant for residents. This trip was also taken predominantly by men, and children, too, interested in the functioning of power plants dealing with renewable energy sources. The leader of the NGO emphasised that *"(...) the trip has allayed many doubts, (...) there were men who took a bike trip only once, the one to Buczek to be precise, only to satisfy curiosity, to dispel doubts, to learn more"* [I2].Another group visiting the biogas plants comprises people interested in obtaining and using organic fertiliser: local farmers and owners of agricultural enterprises. Regardless of the biogas plant type, such meetings are viewed very positively. The visitors underlined the fact that the biogas plant manager is communicative, performs well as a mentor, and provides thorough information about biogas and organic fertiliser (Table 6).

Table 6
Results of Spearman's rho correlation

Do you know the AD off-farm plant in Buczek?	Yes, I was there
I was at a meeting about fertilizer	0.418**
my friends, family work there	0.247**
What do you think about the AD plant?	
we are losing tourists	0.294*
it supports road renovation	0.247*
How do you assess the visit int he AD plant?	
I have learnt new things about energy and biogas	0.516**
what the head of the AD plant says is very interesting	0.516**
I like to get to know new places	0.490**
How does the AD plant support the inhabitants?	
tours come to the plant	0.247*
Who works with the AD plant?	
it cooperates with agri-food companies	0.353**
source of income – work in an agricultural farm	0.258*

Do you know the AD on-farm plant in Stonava?	Yes, I was there
Have you ever visited the AD plant?	
I knew that there was an opportunity to visit, but I didn't take it	0,292**
Yes, I have been there with a tour	0,415**
Yes, I have come there alone	0,611**
What do you think about the AD plant?	
only the AD plant owners benefit	0,241**
How do you assess the visit to the AD plant?	
what the head of the AD plant says is very interesting	0,292**
I have learnt new things about energy and biogas	0,509**
How does the AD plant support the inhabitants?	
it support roads built	0,257**
How do you assess the biogas plant's help in organizing events?	
employees had fun together with the residents	0.166*
biogas plant's personnel talked about the sale of fertilizer	0.193**

Explanations: ** Correlation significant at 0.01 (two-sided); * Correlation significant at 0.05 (two-sided)
Source: Own survey.

4.3. Assessment of AD plants

When answering the question regarding the assessment of the biogas plant, local residents predominantly mention economic matters determining their standard of living. The statement,*" It is good that it is there, it provides workplaces",* received 61% of indications in the case of the off-farm biogas plant and 51% with a reference to the on-farm biogas plant. Other answers, both positive and negative, also occur. The off-farm biogas plant is appreciated by the local community for its participation in promoting the village and the neighbourhood, financial support for the schools, the voluntary fire brigade, or cooperation with local companies. At the same time, the presence of the biogas plant gives rise to controversies because residents quite vividly share their opinion about the aesthetic aspects when they say that "*it is smelly and looks ugly*, or that *they make noise, scare away birds"*. The on-farm biogas plant also receives diverging opinions. It is viewed from the perspective of generating unpleasant smell and the appearance of the facility, but such negative views are significantly less numerous than in the case of the off-farm biogas plant. The local residents also note the positive aspects of the plant's operation (Fig. 5).

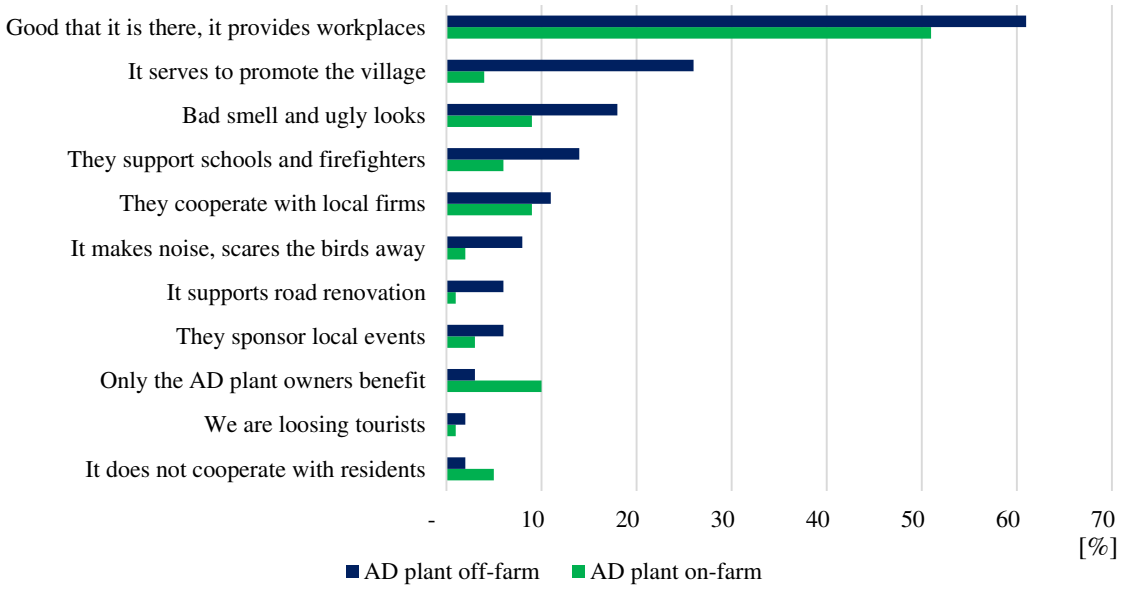


Fig. 5. The distribution of the answer to the question: *„What do you think about the AD plant?"*

Source: Own survey.

Extremely negative opinions regarding both analysed biogas plants are voiced in the statement: *bad smell and ugly looks*. This remark is accompanied by others, similarly critical: *it makes noise, scares birds away* and *we are losing tourists*. A matter raising reservations of the local community in the off-farm biogas plant model is the distribution of organic fertiliser bought by local farmers and its subsequent application. A local government member said: *The removal of the digestate causes inconvenience and this is kind of the main problem I see with the construction and exploitation of such installations"* [I5]. The opportunity to purchase ecological, cheap and effective organic fertiliser is relatively new for both farmers and other residents; therefore, it requires meetings and public discussion. Characteristically, negative opinions about the on-farm biogas plant are accompanied by the statement: *I knew that there was an opportunity to visit, but I didn't take it* (Table 7). This leads to a reflection on the need to educate and provide information to the society on the principles of biogas plant operation, but also to raise an awareness that it is an integral part of an agricultural enterprise well-known to (and positively assessed by) the residents.

Table 7
Results of Spearman's rho correlation

What do you think about the AD plant in Buczek?	bad smell and ugly looks
Good that it is there, it provides workplaces.	-0.424**
It serves to promote the village, commune, and county.	-0.278*
It makes noise, scares the birds away.	0.310*
We are losing tourists.	0.263*

What do you think about the AD plant in Stonava?	bad smell and ugly looks
We are losing tourists.	0.247**
Have you ever visited the AD plant?	
I knew that there was an opportunity to visit, but I didn't take it.	0.247**
Do you know companies supporting the residents?	
Local events are organized only by residents.	0.200**

Explanations: ** Correlation significant at 0.01 (two-sided); * Correlation significant at 0.05 (two-sided)
Source: Own survey.

5. Discussion

The two analyzed modes of AD plants operation translate into various courses taken by the processes whereby such enterprises become embedded in the local environment. Such embeddedness is here defined from the perspective of relations formed with such an environment. The first of the analyzed modes, the AD off-farm plant, initiates and expands its interactions connected with the creation of a network of collaborators on individual production stages. The second model, the AD on-farm plant, functions in the local environment within an existing agricultural enterprise (they have functional ties) and this is usually the intermediary that creates the links with local entities. As a result, a portion of the local society is not aware of the existence of the AD plant, even though they have excellent knowledge of the agricultural enterprise operating in the area and the relations developed by that entity (please see Table 8for the summarized results of the conducted interviews).

Table 8

Embeddedness of AD enterprises in the light of interviews results

Stakeholders	AD off-farm in Buczek	AD on-farm in Stonava
	Relations and alliances created by AD plants	
Operatorsof AD plants	-Recruitment of employees from the local community. -Institutionally supported cooperation with the local community (the linking entities are: school, the village head, NGOs).	
	-Cooperation with companies from the agri-food industry from all around Poland in the acquisition of substrates. - Sustained cooperation with a large local farm – the plant's contractor for the supply of substrates and collection of organic fertilizer. - Periodical cooperation with local farmers operating within a maximum of 15km from the AD plant in the distribution of organic fertilizer.	-Cooperation with representatives of local institutions, including the local authorities, the school and others in the construction of a heat pipeline powered by the heat from the AD plant.
Other entities	-Interactions with the local community. -Support for cyclical events and local activities, local organizations.	
	-Cooperation with local transport companies and neighbouring farmers in the distribution of organic fertiliser. -Cooperation with a large local farm in the acquisition of substrate for biogas production and the collection of organic fertilizer.	-Cooperation with NGOs. -Sustained relations with people living in the immediate vicinity of the AD plant.
	Awareness of AD plants	
Operatorsof AD plants	-Disseminating knowledge about renewable energy and biogas plants by hosting trips to the biogas plant comprising various social and occupational groups.	
	- Meetings and workshops with residents regarding the production of energy from biogas and the properties of the produced organic fertilizer carried out at the pre-investment stage and during the operation of the AD plant.	- Meetings and workshops with residents regarding the production of biogas and energy from biogas at the pre-investment stage. -The organisation of a study visit for residents to another existing AD plant at the pre-investment stage.
Other entities	-Dissemination of knowledge concerning biogas and organic fertilizer during local events (information stands and points).	-Visits to the AD plant held by different social and vocational groups and an opportunity to confront one's knowledge with people living in the immediate vicinity of the AD plant.
	Assessment of AD plants	
Operators of AD plants	-New job opportunities in rural areas.	

	- Unstable legislative and financial situation in the Polish energy market forcing enterprises to seek new development opportunities and a reduction in production costs, e.g. through the use of other substrates to produce biogas.	**-**The biogas plant was established as a response to increasingly unpleasant smells on the farm related to livestock farming. **-**Circular economy production: substrates are supplied by a farm that uses linear infrastructure; similarly, organic fertilizer is collected by the farm.
	- New job opportunities in rural areas. -Increased tax income for local authorities and institutions. -Local production of 'green' energy (electricity and heat). -A role in the creation of a local low-emission economy.	
Other entities	-The enthusiastic reception of the AD plant at the beginning of its operation, until changes in the structure of substrates, were introduced and the distribution of organic fertilizer began. -Unfavourable assessment of the AD plant, but despite of the binding legal regulations allowing enterprises to change the structure of substrates for biogas production during their functioning. -Inconvenience, mainly with regard to odour, related to diversified distribution: transport and application of organic fertilizer. -Positive assessment due to the use of waste to produce biogas.	-Positive assessment of the AD plant resulting from the reduction of unpleasant smells coming from the farming of livestock on the farm. -Inconvenience resulting from increased road traffic and pollution of roads connected with the transport of substrates and organic fertilizer to arable land. -Agricultural monoculture related to the growing area of maize crops – the primary substrate for biogas production.

Source: Own survey

The analysis conducted has indicated that the developed relations which evidence the embeddedness of AD enterprises in the local environment prove that AD plants might be specified more as rural enterprises than just enterprises in rural areas, as they rely in their operation on local resources and at the same time they are grounded in the local economies and local social structures. There is no doubt that their occurrence creates value not only for the operators but also for places where the enterprises are located. Their rurality is expressed by their embeddedness and rooted in the specifics of rural structures. They cannot be 'disembedded' due to their involvement in the local context (Korsgaard et al., 2015). As noted by Domański (2004), entities operating in sectors using agricultural production, which AD plants are a part of as users of agricultural wastes, are typified by their strong connections at the local (and regional) level that are indicative of their groundedness in the local (rural) contexts.

The fact that both studied AD plant modes of operation are grounded in the local environment is visible in their endeavour to take up a number of activities to include the local communities in their profits and reduce costs resulting from conducting business in a given area. They also provide a framework to allow entrepreneurs to learn about one another. These initiatives, together with the relations they form, are institutionalized, i.e. they are carried out with the support of local institutions, including local authorities and NGOs, which legitimizes projects implemented by AD enterprises. The ties that are created and often continue on private terms determine the recognisability of a company which is enormously important in rural areas that are characterized by closer relations between producers on the one hand and consumers on the other. These ties also significantly contribute to the effectiveness of AD business operations. They prove to be helpful in learning and adapting to the local social contexts and local rules. The managers of AD plants all stated that they are constantly looking for employees among the local community. The hiring of people from the immediate vicinity of AD results from learning local conditions that help enterprises to alleviate eventual threats to their AD business and provides the local community with a certain guarantee of security (e.g. in case of random events or technology failures). Such actions are critical for the smooth operation of both AD plants that are operated by off-community investments and on-farm mode, too. Jack and Anderson (2002) come to a similar conclusion when studying the embeddedness of tourist companies in rural areas. They confirm that local residents who are employees of these companies are considered to be loyal and devoted as their presence in the company's team reduces the risk associated with running the business.

New jobs offered by AD plants are also among the most important matters conducive to the local community's positive perception. It has to be stated that AD operation, in comparison to generation of renewable energy from other sources, requires continuous placement of jobs (Bluemling et al., 2013; Wirth et al., 2013). At the same time the development of extensive business relations determines the creation of a competitive advantage of AD enterprises both from the point of view of the energy market and the local economic environment (Dobronte, 2018). According to the study by Dvorak, et al. (2017) and Sidorczuk-Pietraszko (2015), among all renewable energy installations, AD plants offer most workplaces per 1 MW of installed capacity. For instance, in Poland, the average workplaces index for AD plants is 1.85 persons/MW. It is almost twice as much as the second-ranked water power plants which generate employment at 0.98 persons/MW (Sidorczuk-Pietraszko, 2015).

The perception of AD plants is also influenced by actions which may be carried out by their owners or managers due to insufficiently precise legislation that regulates the energy market resulting from a change in the direction of the energy policy (Ciervo and Schmitz, 2017). The transformation of the energy sector in Central Europe in recent years has been directed by EU funding (Chodkowska-Miszczuk et. al, 2016), and domestic subsidies (Dvorak, et al., 2017). Long-term and stable legislation and the financial situation regarding the operation of such enterprises is crucial for their proper functioning. Indeed, legal loopholes enable them to take actions which surprise the local community, e.g. by modifying the structure of feedstock (from purpose-grown maize to waste) for biogas production dictated by their worsening economic condition, which in turn stems from drastic cuts of subsidies for green energy (Chodkowska-Miszczuk et. al, 2017). Therefore, there is a need to tighten legal regulations, clarify the conditions for monitoring biogas installations and criteria for evaluating their functioning, and preserve financial equilibrium in the renewable energy market, especially because local decision-makers perceive AD plants as important elements in the development of local low-emission economies.

Any such actions in the scope of modifying biogas and energy production should take into account the opinion of the local society (Wüstenhagen et al., 2007). Therefore, it is invaluable to consult and discuss those matters with the residents not only at the pre-investment stage but also during the operation of the enterprises (Soland et al., 2013). Moreover, such meetings may and do create convenient circumstances for residents to acquaint themselves with the issues of energy transition, the establishment and functioning of AD plants. Our results show that people who participated in meetings regarding the use of

organic fertilizer and visited the biogas plant confirmed that they had the opportunity to take an in-depth look into matters concerning energy transition and aspects related to the operation of AD plants. They also knew the ventures undertaken for the local community with the participation of the biogas plant investors. In turn, people who knew about the opportunity to visit the AD plant but did not take it, had a negative view of the enterprise, mainly in terms of the unpleasant smell and ugly looks. This is in line with the results of the previous studies (Frantal et al., 2017).

In the light of what was said above, the relations developed by biogas AD and their endeavours to learn the local social structures and integrate with the local economic environment—the manifestations of embeddedness—contributed to the informal education of the local society concerning the transformation of the energy sector in rural areas. The dissemination of knowledge regarding changes occurring in the energy sector, including the use of biogas as a renewable energy, is a key element in the development of the energy sector. The diffusion of information related to renewable energy determines the understanding and acceptance of the ongoing changes. It also contributes to the formation of ecological awareness in society and to behaviours and attitudes characteristic for a low-carbon society. In this respect, AD plants fulfil the demand to promote informal energy education (Acikgoz, 2011), and in particular renewable energy sources education (Jennings, 2009, Karabulut et al., 2011). Moreover, AD plants as enterprises grounded in the local context and with a network of links have an opportunity to become local leaders (frontrunners and first movers, Kaphengst and Velten, 2014) in the process of energy transition in rural areas.

The embeddedness of biogas plants in local society contributes to the transformation of the energy sector in rural areas. As M. Vancea et al. (2017) confirmed, other actors such as social organizations or entities play crucial roles in social energy transition at local level. The process whereby biogas enterprises becomes grounded in the local environment through creating relations with different local entities and becoming involved in the local context promotes the dissemination of the latest trends in the energy sector and education covering changes in the same. Embeddedness also allows the entrepreneur to play the role of a leader of change, particularly as local decision-makers stress the importance of biogas plants in the development of plans for a low-emission economy. Therefore, the contribution of embeddedness should most certainly be included in the process of developing strategies and long-term plans for rural energy transition.

Conclusion

In our paper, we aimed to evaluate the operation of two modes of AD plants (on-farm and off-farm) through the lens of their embeddedness into the life of two rural communities. We surveyed cases of two municipalities in Poland and the Czech Republic. We found that despite the site-specific character of both researched AD plants certain differences in the level of their embeddedness could be identified. We know that AD plants are rural enterprises and thus they are specific as they rely on local resources, are more grounded in the local economies and local social structures than usual enterprises. It seems that the grounding of AD plants in the local environment is tangible in both cases.

We have found that regardless of the kind of business model applied (on-farm or off-farm), both AD plant types create significant linkages with a diverse set of entities. In order to carry out its business operations effectively, the off-farm AD plant (in Buczek) more distinctly builds relations in the supply chain, both with substrate suppliers, local and regional agri-food enterprises on the one hand, and local farmers on the other. The on-farm AD plant (Stonava) solely relies on substrates that have been generated by a local farm that the AD plant is an integral part of. Thus, the on-farm AD plant is less active in building relations in the supply chain.

Most respondents in both surveys are persuaded that AD plants in their communities cooperate primarily with local farmers, secondly with the local authorities. Other interesting results were revealed in the opinions of the representatives of the regional authorities as they believe that the relations of the AD with the local environment are primarily dependent on the relation of the AD with local authorities. Regional authorities strongly emphasized personal links of AD operators with local mayors as one of the possible ways to develop projects for heat supplies for the local community. The relations of the AD with the local population were rather underestimated. In our opinion this result shows certain particularity that significantly affects the development of AD plants (and generally local planning) in Central-European countries. Lack of participation of local population (and other stakeholders as NGOs, civic action groups) in local planning means that opinions of locals are frequently not heard or not taken into account. Deficient participation in local decision-making has gradually grown through the era of communism and until today it seriously influences and deforms local planning. Thus, negotiations between operators of AD about possible benefits of location of such facility on the area of community are usually reduced to agreement with local mayor and

involvement of other groups of stakeholders is rather rare. Suškevičs et al. (2019) articulated this problem as lack of trust in authorities.

Nevertheless, we revealed that enterprises also become more embedded in the local environment through expanding and strengthening contact with the inhabitants of communities where they are located. AD plants are usually not large local employers but even the psychological effect of giving at least some jobs to local people seems to be beneficial. The importance of local employers is increased in case of failures or incidents in the AD plant when they are able to assist and solve critical situations very quickly.

For the level of embeddedness of the AD plant into the life in the community, the support for local institutions (schools, citizens associations), cultural events or renovations of local roads seems to be of a crucial importance. Such support is mirrored in the awareness of AD among the local population, which is rather high. On the other hand, we found that a group of the population that is less aware of the AD in their own municipality are women who have lived in the municipality for a longer time. This is in line with another finding that men are more frequent visitors of the AD than women. Generally, the visits of the locals in the AD are important for developing positive attitudes to this facility. Negative opinions are more frequently connected to the respondents who had never visited AD plant before. The diffusion of knowledge about biogas production determines the understanding and the acceptance of the ongoing changes. Furthermore, the relations developed by biogas enterprises contributed to the informal education of the local society concerning the transformation of the energy sector in rural areas in the context of biogas production.

One more fundamental finding is that the multiple dimensions of embeddedness do not always push together in a positive direction. So, one way to build mutual relations among AD and the loca lpopulation is the distribution of digestate (one of the products of the AD) as fertilizer to local farmers. However, treatment with digestate is quite a controversial issue as it requires experience due to possible odour leakages. There is no doubt that more education and provision of further, clearer information and instruction is needed in this case to ensure the smooth and beneficial coexistence of AD plant in the host community. Similarly, when answering the question regarding the assessment of the AD plant, the local residents predominantly mentioned economic matters (like provision of jobs) that determine attitudes towards AD. At the same time, the presence of the AD plant also gives a rise to the controversies connected to the aesthetic aspects of the AD ("…it is smelly and looks ugly…makes noise…") which is less frequent in the case of the on-farm AD.

To sum up, many problems are connected to the embeddedness of the AD plant in the life of rural communities. In this paper, we tried to capture differences between cases of the AD on-farm and the AD off-farm systems. However, to make the picture clearer, more research has to be conducted that takes into account, for example, informal networks AD operators and providers of substrates for particular AD plants. Which mode of AD operation is more beneficial for local rural development is a rather simplistic question to answer. The embeddedness of both modes of AD plants operation is rather of a complex nature and site-specific, as it involves not only measurable, materials facts but also subjective perceptions of involved stakeholders.

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