The role and perception of biogas in the energy transformation in Slovakia

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Abstract: *The energy transformation of EU countries brings challenges in the field of energy policies and forms of state support. Moreover, the introduction of new technologies and the production of energy from renewable sources often face resistance and negative attitudes from the population. Slovakia is a country, which, in addition to decarbonisation, needs to diversify resources and reduce energy dependence on Russia. Especially after the Russian attack on Ukraine in 2022. One of the forms of energy production that has experienced rapid growth is anaerobic digestion in agricultural biogas plants. In the example of Slovakia, this study evaluates the impact of European and national energy policies on changes in the energy mix and the development of energy production from biogas. Subsequently, in the form of guided interviews with biogas plant managers and mayors, and a questionnaire survey in the affected municipalities, it identifies the perception of biogas plants and identifies the factors that shape it. The results show that after the optimization of national energy policies and forms of subsidies, the rapid development of energy production from biogas has slowed down. However, the lessons learned from the case studies offer important insights on how to eliminate the resistance of the local population to the operation of a biogas plant and the overall negative attitudes towards this form of energy production. All the surveyed communities sensitively perceive the negative effects of the biogas plants operation. However, in communities that share the benefits from the plant´s operation (taxes, sponsorship, good image, established economic activities, and new jobs), the plant acceptance is much better. Technology as such, as well as the idea of building additional biogas plants, have much better support in these communities.*

Keywords: *agricultural biogas plant, renewable energy, Slovakia, perception*

Introduction

Global energy consumption and its environmental impacts are constantly growing, and so is the social and political importance of this issue. The need to transform the traditional energy system is widely accepted. Although approaches to such a transformation vary among experts and in national policies, they agree on the need to eliminate the use of fossil fuels in favor of renewable and low-emission energy sources. In many regions and countries, including the United States and the European Union, the transformation is also linked to a reduction of economic and geopolitical vulnerability stemming from dependence on import of the fossil energy sources (Bluszcz 2016, Mata Pérez, Scholten and Stegen 2019, Miciuła, Wojtaszek and Włodarczyk 2021).

EU legislation on the promotion of renewable energy sources has also developed significantly over the last 15 years. In 2009, EU leaders set a target of a 20% share of renewables in EU energy consumption by 2020 (Directive 2009/28/EC). In 2018, a target for 2030 was set to 32%, which was even increased in 2021 to 38-40% (Directive 2018/2001, Directive 2021/550). With regard to the EU's goals, Slovakia was to increase the share of energy produced from renewable sources to 14% by 2020, which it achieved in advance (Chodkowska-Miszczuk et al. 2020). Energy policies and the ways in which financial support instruments

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are set up appear to be key instruments in supporting renewable energy production in Central European post-socialist countries (Chodkowska-Miszczuk, Kulla, and Novotný 2017). However, as in other parts of the world, new projects often struggle with negative perception and resistance from the local population (Upreti and van den Horst 2004, Magnani 2012). Thus it is very important to identify examples of good practice in this area and to make recommendations from them. In NextGenerationEU – the largest stimulus package during the existence of the European Union, the goal to make Europe a climate-neutral continent by 2050 is a priority (European Comission 2021). With such an ambitious goal, it is essential to deal with the social acceptance of the use of renewable energy sources.

Taking into account traditional energy sources (nuclear, coal, natural gas), Slovakia is almost completely dependent on their imports. That is why the development of the use of renewable energy sources is of great importance in the country. Of the renewables, hydropower and photovoltaics are the most developed. Over the last 20 years, there has also been a significant development in the production of energy from biogas (Chodkowska-Miszczuk, Kulla and Novotný 2017, Janíček et al. 2017, 2018). However, the rapid development of this segment has also brought considerable resistance from the population, due to which several planned projects have been stopped.

The aim of this study is to assess the role of agricultural biogas plants (ABPs) in the process of transformation of the energy system of the Slovak Republic and to identify regularities and differences in the perception of ABPs by the population. For that purpose, a case study of northwestern Slovakia, which is characterized by a large concentration of ABPs in a small area, is employed. Based on these findings a possible vision for the future use of existing ABPs is outlined.

Conceptual background

Policies towards Green Europe idea: Renewable energies in the EU and Slovakia

Energy production in the European Union is linked to two key problem areas. On the one hand, it is the largest source of greenhouse gases, and on the other hand, it is highly dependent on the import of energy raw materials. This is especially problematic for oil (97% imported) and natural gas (90% imported) and it increases the EU's energy, economic and geopolitical vulnerability. The recent enormous rise in gas and electricity prices is also a manifestation of this vulnerability (EPN 2021). Nuclear energy production has decreased recently, but it still covers almost 25 % of electricity produced in the EU (Eurostat 2022b). Uranium imports are nearing 100% of its consumption, however, unlike fossil fuels, its distribution in the world is more even (about 20% of imports currently come from Niger, Russia, Kazakhstan, Canada, less so from Australia, Namibia, and other countries). This, together with the possibility to build up nuclear fuel reserves for several years to come, means that the production of nuclear energy does not increase the EU's vulnerability significantly. Even though nuclear energy production does not generate greenhouse gases, it is under pressure, mainly for concerns about the safety of the production and storage of radioactive waste (Jančura and Prozbík 2019, Eurostat 2022).

Reflecting these circumstances, the EU is taking steps to build the Energy Union. In 2015, the Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy was presented (Directive (EU) 2015/080). The ambition of the strategy is to make the EU a common energy system in an efficient manner using locally available, renewable energy resources and intensively developing low-emission technologies. Moreover, the EU energy policies aim to regulate a proportion of energy produced from RES in each member country by appropriate documents among which the fundamental one was the Directive of the European Parliament and the Council no. 2009/28/WE (Chodkowska-Miszczuk, Kulla and Novotný 2017). In 2018 it was repealed and replaced by the Directive (EU) 2018/2001 on

the promotion of the use of energy from renewable sources and Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action which introduced a new, binding, renewable energy target for the Union for 2030 of at least 32%. The target was later even increased to 38-40% (Directive 2021/550). In 2020, the EU adopted the NextGenerationEU (NGEU), the temporary instrument designed to boost the recovery and help to rebuild a post-COVID-19 Europe. When considering funding, the first and the most important NGEU´s pillar is to make Europe green – to make it a climate-neutral continent by 2050. Such massive financial and institutional support has the potential to strengthen the role of renewable energy in the energy mix of individual EU countries. In 2022, the European Commission proposed including nuclear and gas power in the bloc's sustainable finance taxonomy (Euractive 2022). Even though these technologies were included in the taxonomy only as "transitional", some countries may prioritize them over the RES. At the same time, it may slow down the reduction of dependence on natural gas imports, which appears to be problematic in terms of the EU's energy vulnerability.

Slovakia is a country poor in energy raw materials. Almost 90% of primary energy sources are imported. The only major domestic energy source is brown coal. However, in line with the EU's goals, its mining has been gradually declining and should quit in 2023, as well as the burning of coal for energy production (PPCA 2020). Therefore, it can be expected that in the coming years nuclear energy, which currently covers about 56% of total electricity production, will still be the most important in Slovakia. In addition, a new unit of the Mochovce Nuclear Power Plant is expected to be launched in 2022 (WNN 2021, SITA 2022). Launching a new unit will change the power balance of Slovakia from imports to exports. However, it will statistically reduce the share of energy produced from renewable sources. The second most important source is hydropower, which provides 16% of electricity. Thanks to this composition of the energy mix, Slovakia is a country that has low emissions from electricity production. Still, it needs to intensify the use of RES and increase their proportion in the energy mix.

In comparison with the Visegrad Group countries (V4 – Czechia, Hungary, Poland, Slovakia), the energy intensity of Slovakia is the lowest in the long term, and it even decreased considerably since the early 2000s. Nonetheless, Slovakia remains among the most energy-intensive economies in the EU, especially given the structure of industry, as it consumes almost 80% more energy per unit of GDP than the EU average (MENVSR 2020). This makes the transformation of the energy system in Slovakia even more important.

After 2000, several laws and strategies were adopted supporting the use of renewable energy sources in Slovakia. Chodkowska-Miszczuk, Kulla and Novotný (2017) provide a detailed overview of these documents. Directive 2009/28/EC on the promotion of the use of energy from renewable sources for Slovakia resulted in a commitment to achieve a 14% share of energy from renewable sources in gross final consumption by 2020. Reflecting this, the National Renewable Energy Action Plan (MESR 2010) was adopted in 2010 (MESR 2010).

Gross final consumption includes all energy consumed by end-users and power plants. According to Eurostat (2020), Slovakia managed to reach its goal in 2019 (Fig. 1). In 2018, it seemed that Slovakia would not meet it, but between 2018 and 2019 the share increased sharply from 11.9 to 16.9%. However, the reason was not a sudden change in the energy mix, but updated data on biomass consumption in households based on the new data from a survey of households carried out by the Slovak Hydrometeorological Institute and Statistical Office (Jenčová 2021).

Support for RES contributes to energy self-sufficiency, the elimination of greenhouse gases, can stimulate technological development and innovation, and eliminates the economic, energetic and geopolitical vulnerability. It also provides new job opportunities even in rural areas. The negative side of some forms of RES is mainly the price of energy (Chodkowska-Miszczuk, Kulla and Novotný 2019). The energy produced by solar, wind or biogas plants has long been several times more expensive than energy from nuclear, hydroelectric or coal-fired power plants (IEA 2021). However, the sharp rise in fossil fuel prices in recent months could contribute to the competitiveness of renewable energy.

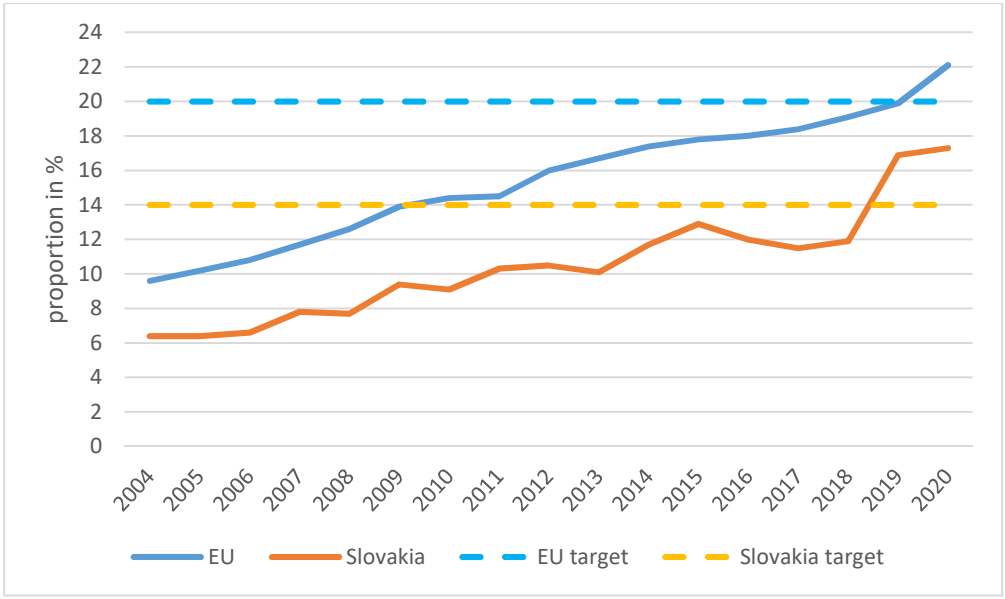

Fig. 1. *Share of energy from renewable sources (in % of gross final energy consumption) Source: Eurostat (2022a)*

Biogas as a renewable energy source in the EU and Slovakia

The oil crisis of the early 1970s, as well as the development of modern technologies, stimulated the development of energy production from biogas. In 1985, there were 75 biogas plants in operation in Germany. In 2013, there were already more than 14,500 ABPs in Europe, of which more than 9,000 were in Germany and almost 1,400 in Italy. In the Czech Republic, which is a pioneer of such energy production in the post-socialist EU countries, 500 ABPs with an installed capacity of almost 400 MW were already in operation in 2013 (Chodkowska-Miszczuk, Kulla and Novotný 2017). This period represents the biggest boom in building ABPs in Europe. In Germany for example, the number of plants was increasing by more than a thousand a year in the period 2009-2011 (Torrichos 2016).

It is evident that some European countries have been more successful than others in exploiting their domestic potential for biogas production. For example, Germany produces more than 1 MWh per person and year, France, Norway, and Sweden only around 0.2 MWh per person and year. The average for the EU-27 is nearly twice as high, just under 0.4 MWh (calculated based on Eurostat 2021a, b). The production in Slovakia is only 0.1 MWh per person and year (Energy 2020). However, there is a potential for production in Europe even higher than currently achieved in Germany. This shall be obtained mainly by agricultural biogas, but there is also a potential for increased anaerobic digestion of sewage sludge and municipal organic waste in some countries (Gustafsson and Anderberg 2022).

The development of biogas plants in Slovakia, as well as in other Central European countries, significantly affected the adopted legal framework and the deployment of financial support for energy production from RES. Chodkowska-Miszczuk, Kulla and Novotný (2017) identify that relationship during the period of rapid development of biogas energy production and agricultural biogas plants construction from the mid-2000s to mid-2010s. They also provide a thorough insight into the support mechanisms that contributed to the growth. The support mechanisms are similarly with other EU countries (cf. Gustafsson and Anderberg 2022) based mainly on feed-in-premiums, feed-in-tariffs, or tax exemptions. Gustafsson and Ander-

berg (2022) summarize that the generous financial support in most of the countries was guaranteed for a very long time horizon, which made investments in biogas energy production very attractive on the one hand, but began to put an unsustainable burden on future state budgets and distorted the competitive environment (cf. Chodkowska-Miszczuk, Kulla and Novotný 2017) in renewable energy production. Therefore, many countries, including Slovakia, reduced financial support to less attractive levels for new projects. Changes in energy policies and financial support also brought some uncertainty to investors. This is in contrast to the stability and continuity that many studies consider to be key factors in the success of policies in support of the development of biogas energy production (Chodkowska-Miszczuk, Kulla and Novotný 2017).

Perception and social acceptance of biogas plants

One of the biggest obstacles to the development of renewable energy production is the resistance of the local population to such projects (Martinát et. al. 2017, Prosperi, Lombardi, and Spada 2019, Dumont, Hildebrandt and Sempuga 2021, Strober et al. 2021, Kulla et al. 2022). Therefore, social acceptance, defined as the active or passive approval of a policy by the public, is a major challenge in achieving the goals of building renewable energy facilities (Bertsch et al. 2016, Batel 2020). In this regard, it is possible to distinguish between a general public-wide acceptance (or socio-political acceptance) and a local acceptance on the level of community that is directly affected by a particular project (Wüstenhagen et al. 2007). Representative surveys indicate strong support from the population of the European Union (EU) for renewable energy (European Commission 2007, 2010). This means that there is a general public-wide acceptance of the renewable energy projects implementation. However, at the local level, when it comes to a specific project, certain resistance from the local population appears. This discrepancy between general public-wide and local acceptance can be explained by the concept of "Not in my backyard" – NIMBY (e.g. Bell, Gray and Hagget 2005, Devine-Wright 2005, Warren et al. 2005, Van der Horst 2007, Batel 2020). This means the element of the theory of rational choice, which is that human behaviour is motivated mainly by self-interest (Hunter and Leyden 1995). In the context of renewable energy, this means that people usually support the development of renewable energy only if the facility is not supposed to be in their proximity.

Several scientific studies have examined the perception of biogas plants by residents of the community in which such a facility was built. Segreto, Principe, and Desormeaux (2020) provide a qualitative analysis of 25 case studies addressing the significant factors of social acceptance of renewable energy projects in Europe. They point to the need to better understand the general trends in the local acceptance of RES facilities throughout Europe, thus eliminating negative public attitudes and facilitating the implementation of renewable projects. Of the case studies analyzed, most focus on the acceptance of wind and solar installations, which have a long history in Europe. Biogas is addressed by Upreti and Van den Horst (2004), Zoellner, Schweizer-Reis and Wemheuer (2008), Magnani (2012), Soland, Steimer and Walter (2013), Prosperi, Lombardi and Spada (2019), Chodkowska-Miszczuk, Kulla and Novotný (2019), Martinát et al. (2022), Kulla et al. (2022).

Martinat et al. (2017) used a questionnaire survey to examine the perception of three selected ABPs in the Moravian-Silesian Region in the Czech Republic. Their aim was also to identify and provide local governments and investors with suggestions on how to avoid mistakes that worsen public perception. The survey shows that the basic condition for social acceptance of ABP is to maximize the benefits for the local population and minimize the negative

impact on their quality of life. It is also clear that there is a higher level of acceptance in municipalities where ABP construction plans were regularly consulted with the local population and where there is cooperation and trust between the plant operator and the municipality.

The perception of ABPs in three communities in Poland, Czechia, and Slovakia is addressed by Chodkowska et al. (2020). Among surveyed countries, respondents in Slovakia have the most negative attitude towards the ABPs in operation. The most common reasons for negative attitudes comprise odour, noise, absence of benefits for the community, unrealized projects for the use of heat, etc. In order to identify regional and individual advantages and disadvantages as well as the acceptance of ABPs by the local population, Kortsch, Hildenrand, and Schweizer-Reis (2015) conducted qualitative research in four municipalities in East Germany. Respondents cited odour, noise, excessive targeted corn cultivation, and increased traffic as the biggest negatives of ABPs. Among the positives, they mentioned the economic benefits for the municipality and the ecological way of energy production. Schumacher and Schultmann (2017) offered largely similar results on biogas perception, addressing residents living 1 km or less from the ABP. Of the respondents, only 18.5% accept a distance from the ABP of less than 1 km. In a study by Bertsch et al. (2016) it as many as 40%, but residents living at a greater distance from the ABP were also addressed here.

Data and methods

Study area

When evaluating the policies and the role of energy production from agricultural biogas, we took into account Slovakia as a whole. However, we examined the perception and social acceptance of biogas energy in detail in a specific territory of north-western Slovakia. The selected area is characterized by a high spatial concentration of ABPs. There are nine of them in five villages on the approximately 50 km section in the Váh River valley (there are two in one village and even four in another) in the Trenčín county (Fig. 3). The total installed capacity of these ABPs is 12 MW, so it is clear that the average installed capacity is over 1 MW, and thus that they are large ABPs. The smallest ABP is in Mestečko, its installed capacity is 0.68 MW.

In addition to the spatial concentration of ABPs, the surveyed area was chosen because all localities in which we examined ABPs are characterized by similar geographical, natural and social-economic characteristics. Such similarity at least partially eliminates the influence of these characteristics on the differentiation of the perception of ABPs by local actors and the population. This allows for a better understanding of the role of relationships between the ABP investor, the municipality, and the local population.

It is a relatively densely populated and one of the most industrialized areas in Slovakia. It is important for the functioning of ABPs that agriculture is also developed in this area. Livestock production focuses mainly on cattle, sheep, and poultry. The cultivation of potatoes and less demanding cereals and fodder is of great importance in crop production. As a result of the operation of ABPs in the region, a sharp increase in the sown area of maize in recent years has been recorded. For example, in the district of Ilava (where Horovce and Kameničany are located), it increased from 426 hectares to 1,208 hectares in the period 2009-2017.

We conducted controlled interviews with ABP operators and mayors in five rural communities (Horovce, Mestečko, Trenčianska Teplá, Veľké Bierovce and Kameničany; fig. 2). A specific case is ABP, which is located in Kameničany, but at about the same distance from the village Slávnica. Kameničany and Slávnica form a compact built-up area, but from an administrative point of view, they are separate municipalities. We, therefore, conducted a guided interview also with the mayor of Slávnica. We conducted a questionnaire survey to

explore the perception of the population in two communities that we selected based on the shortest distance of APBs from residential areas, and the intensive and sensitive perception of the ABPs by the local population indicated by mayors during the interviews. This way we selected ABPs in Horovce, and in Kameničany and Slávnica. We considered Kameničany and Slávnica as one community, but the questionnaire survey in some aspects also showed a differentiated perception between these municipalities, which we point out when interpreting the results. All surveyed municipalities have 500 – 700 inhabitants. An exception is Trenčianska Teplá with more than 4,000 inhabitants.

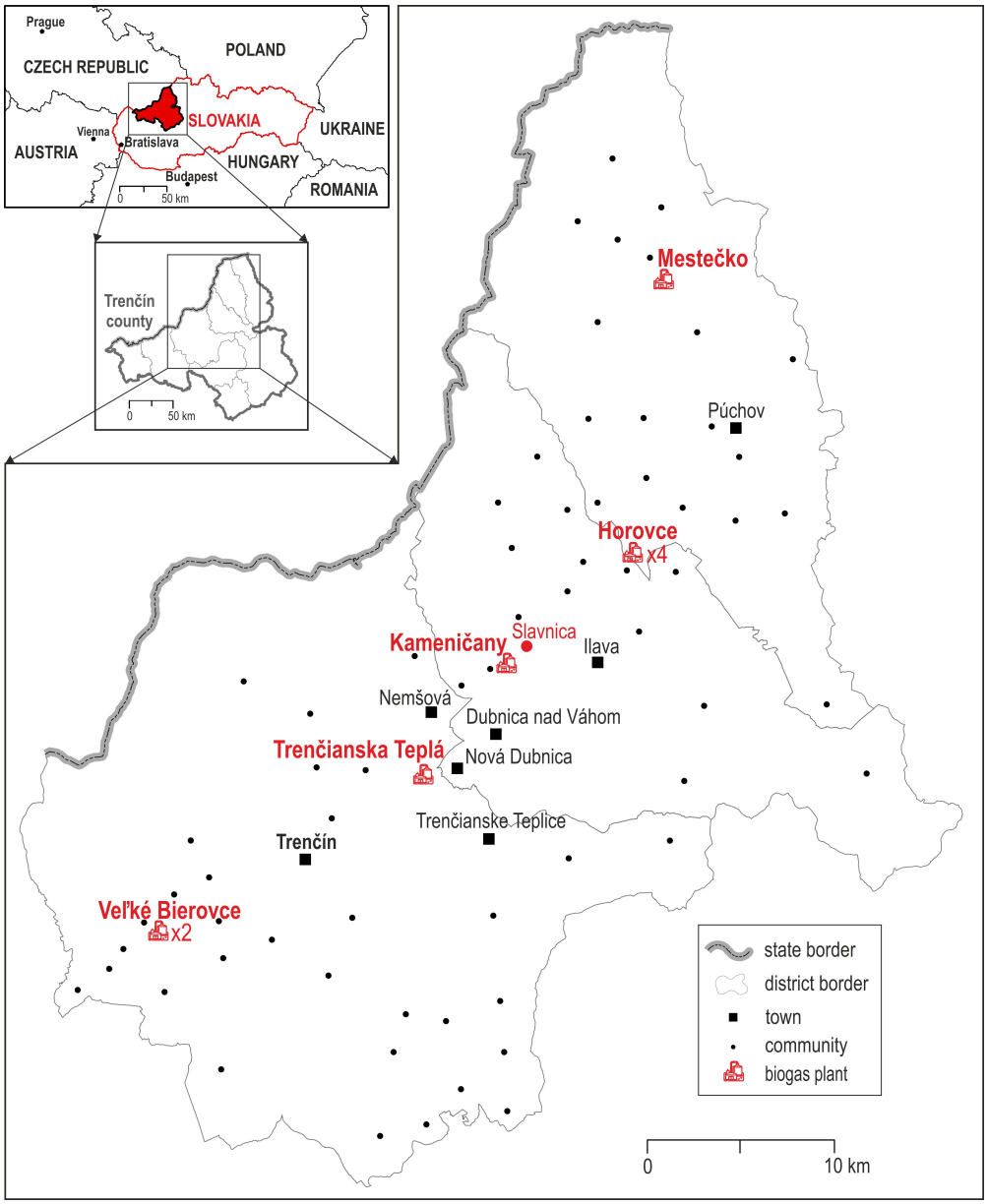

Fig. 2. *Geographical location of the case study communities*

The researched ABPs were built during the period of the biggest ABPs construction boom shortly after 2010. Their relatively large installed capacity is in line with the subsidy policy at the time and suggests that their investors were more focused on profit than on agricultural waste treatment. The range of substrates used is quite diverse but the maize is usually a basic substrate. It can be considered a positive that all biogas plants process beet cuttings from the sugar factory in Trenčianska Teplá, with the use of which the factory had major problems in the past. Livestock waste (cattle manure, poultry manure, and whey) is sourced from local suppliers. Due to its high need, corn silage is also imported from more remote regions (about 100 km in the case of BPS Kameničany). In recent years, the proportion of food waste in the substrates has also increased.

In 2012, a law was passed requiring new ABPs to use at least 50% of the heat produced. As the investigated ABPs obtained operation permits before 2012, the heat produced is mostly underused by most of them. It is used to a greater extent in Kameničany and Mestečko. The basic characteristics of the investigated ABPs are given in table 1.

Tab. 1. *Basic information about the biogas plant case studies*

Community	Investor	Start of the operation	Electric installed capacity (MW)	Substrate	Use of heat
Kameničany	NWT company	2012	0.999	Maize, manure, hay	Heating of a large-scale glass-house for tomato production
Horovce	Biotec Company	2010 - 2013	2.996	Maize, rye, haylage, chicken and cattle manure, beet cuttings, food waste, urban greenery	Heating of on-site buildings, halls, offices. The plan for connecting residential homes has never been realized.
Trenčianska Teplá	BEF, s.r.o.	2011	0.999	Beet cuttings	Only fermenters
Veľké Bierovce	Bioplyn Bierovce, s.r.o.	2012	1.998	Maize, sorghum, haylage, cattle and chicken manure, beet cuttings, burnt oil, breadcrumbs	Only fermenters
Mestečko	PD Mestečko	2012	0.680	Cattle and chicken manure, maize, whey	Fermenters and five farm buildings

Based on the information provided by the ABPs´ operators in 2018

Data collection

Following the identification and reconnaissance of the study area, we conducted controlled interviews with mayors and with representatives of operating biogas plants in the April of 2018. The interviews aimed to obtain information from competent persons who provided us with valuable information about the process of preparation and construction of ABPs, their operation, and mutual relations between the municipality and ABPs. The interviews were recorded, which ensured a consistent capture of the thoughts of the interviewees. The interviews provided valuable insights, while also making it possible to identify communities suitable for research into the perception of ABPs by the local population. We conducted a questionnaire survey in Horovce and Kameničany/Slávnica, where ABPs are similarly located, but previous interviews have shown that the relationship between ABPs and municipalities is significantly different, and the electrical capacity installed and the use of heat are also different.

The operators of the ABPs were asked about the following matters:

- Economic aspects of the ABP operation
- Relations and information flow between ABP, municipality, and inhabitants
- Plans with future operation based on attitudes towards current energy policies in Slovakia

The mayors of the given municipalities were asked about the following matters:

- Providing information to the municipality and residents about the operation of the biogas plant and participating in the decision-making process (in the preparatory phase of the ABP project)
- Impact of ABP operation on local development and its benefits for the community
- Attitudes towards the environment and energy policy, support for the RES

The questionnaire survey was conducted in the May of 2018. Qualified interviewers (trained university students) addressed respondents directly on the street in the surveyed municipalities. The population over the age of 18 was addressed in such a way that the structure of the respondents corresponded as much as possible to the structure of the population of the given municipality with regard to gender, age, and educational attainment. The questionnaire contained 13 questions. For the purposes of this study, we used the following questions regarding the perception of the ABP at the time of its planning and after years of operation:

Q1. Was your community sufficiently informed about the plans for the construction of ABP in its planning phase? (fig. 4)

Q2a. Did you agree with the ABP project in your community before its construction started? And Q2b. Would you agree with its construction based on your current experience? (fig. 5)

Q3. Does the ABP operator in your municipality take the residents' reservations about the station and address them? (fig. 6)

The answers to these questions were measured on a 5-point scale (where 1 = definitely yes, 2 = rather yes, 3 = I do not know, 4 = rather no, 5 = definitely no).

Q4. What is your personal attitude towards further development of ABPs?" A respondent could choose from the following answers: a) I don't mind if other ABPs are built in the proximity of my community, b) ABPs should be built but not in the proximity of my community", and c) ABPs shouldn't be built at any locality. (fig. 7)

A total of 234 questionnaires were included in the analysis. Of these, 112 were from Horovce and 122 from Kameničany and Slavnica. We only took into account the questionnaires in which the respondents answered all the questions. The results were processed by common statistical-mathematical methods.

Results and Discussion

In this section, we introduce and assess the current development of energy production from agricultural biogas in the light of Slovak energy policies and with special emphasis on strategic documents and specific measures. Subsequently, we evaluate the results of controlled interviews with ABP operators and mayors, and this is followed by the assessment of local acceptance based on the research on the perception of the local population.

ABPs under the energy policy and strategic plans in Slovakia

The first three ABPs in Slovakia with an installed capacity of 2MW launched the operation in 2005. A more significant increase in the number of ABPs occurs only after the adoption of the Act on the Support of RES no. 203/2009 Coll. (Fig. 3). In 2012, there were 30 ABPs with a total installed capacity of 26 MW (the share in the total installed capacity in Slovakia was 0.35%). The highest number of ABPs was recorded in 2014 and 2015 (76), and the highest installed capacity (93 MW) of ABPs was reported in 2016. The share of total installed capacity in Slovakia then reached 1.4% (tab. 2) and since then the values of all three indicators have been declining slightly.

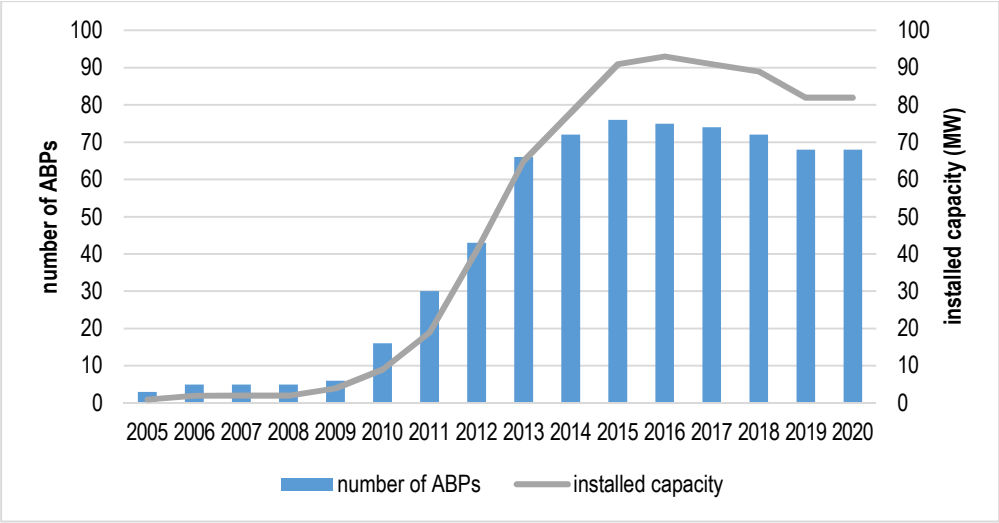

Fig. 3. *Development of agricultural biogas plants numbers and installed capacity in Slovakia*
Source: SOSR (2022)

Tab. 2 shows the position of biogas among RES in Slovakia in terms of installed capacity. It is clear that, despite the sharp growth in the period 2009-2016, the share of installed capacity in biogas plants is only about 2.5% of the capacity of all renewable energy plants. In addition, this share has been declining in recent years. Renewable energies continue to be dominated by hydropower, followed by solar energy.

Tab. 2. *Production Capacity of Electricity in 2009-2020 (MW)*

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hydro Plants	2487	2516	2523	2522	2523	2523	2522	2524	2523	2528	2527	2529
Solar Photovoltaic	-	-	188	513	588	533	533	533	528	472	590	535
Wind	3	3	3	3	5	3	3	3	4	3	4	3
Industrial, Municipal Solid Wastes	6	5	5	5	8	22	22	29	22	22	22	22
Wood/Wood Wastes	160	169	171	169	176	153	145	150	149	148	138	137
Biogases	**4**	**9**	**14**	**26**	**35**	**78**	**91**	**93**	**91**	**89**	**82**	**82**
RES together	2660	2702	2904	3238	3335	3312	3316	3332	3317	3262	3363	3308
% Biogases/ RES	**0,15**	**0,33**	**0,48**	**0,80**	**1,05**	**2,36**	**2,74**	**2,79**	**2,74**	**2,73**	**2,44**	**2,48**
Production Capacity together (including non-RES)	6528	7258	7295	7370	7406	6977	6658	6643	6595	6518	6523	6557
% Biogases Production Capacity together	**0,06**	**0,12**	**0,19**	**0,35**	**0,47**	**1,12**	**1,37**	**1,40**	**1,38**	**1,37**	**1,26**	**1,25**

Source: SOSR (2022)

This development confirms the importance of the legal framework and support instruments. The slowdown in the positive development trend in the production of energy from biogas occurred in 2014, when a new price regulation in the electricity industry came into force according to the Regulation (ÚRSO) No. 221/2013. For ABPs, the proposed concept meant grading the purchase price of electricity according to their installed capacity into four groups (the higher installed capacity the lower price). The most used type, i.e. ABP over 0.75 MW, thus fell into the lowest price category, which led to their unprofitability. In addition, a stop-

state - a general suspension of the acceptance of applications for the connection of electricity generation facilities to distribution systems with an output of more than 10 kW came into force in 2014 (Janiš 2014). The stop-state was supposed to ensure the safety and stability of the power system. It was cancelled in April 2021, when new cross-border interconnections of the Slovak and Hungarian transmission systems were launched, making it possible to connect an additional installed capacity of 1,837 MW to the electricity system (MESR 2021).

These changes in the legal framework brought uncertainty to development plans and suspended new projects. On the other hand, they sparked a discussion about the future of bioenergy in Slovakia. The opinion of AEBIOM (EBA 2016) does not consider the production of bioenergy from silage to be long-term sustainable. It is recommended to focus on agriculture and animal husbandry, which have a significant amount of processable waste. The average installed capacity of such stations should be smaller – up to 250 kW, which would bring it closer to Germany, where the average installed capacity is about 500 kW (Daniel-Gromke et al. 2017). Such installed capacity is supposed to cover the own consumption and partial supply of electricity and heat to the distribution system. In addition, the final digestate is considered a valuable organic fertilizer. Larger biogas plants with an installed capacity of more than 1 MW appear to be an efficient solution for the production of biomethane or the combined production of heat and electricity by burning biogas in cogeneration units.

In 2015, Act no. 79/2015 Coll. on waste, which obliges municipalities and catering operators, to separate biodegradable waste. Together with the current abolition of the stop-state to grid connection (MESR 2021) and potential support for renewable energy investments in accordance with the Recovery Plan (GOSR 2021), this law can be an important step for the future of energy production from biogas. In addition, the conversion of waste into digestate itself would be an added value.

In 2019, Slovakia's Integrated National Energy and Climate Plan for 2021 to 2030 (MESR 2019) prepared pursuant to Regulation (EU) 2018/1999 was adopted. The Plan proposes a target of 19.2% for the share of energy from renewable sources in gross final energy consumption in 2030, which is significantly below the EU target of 32% but for Slovakia, it means an increase of 5.2 percentage points when compared to the target set for 2020. In addition, the Ministry of the Environment of the Slovak Republic declares institutional support for achieving this target in the Strategy of the Environmental Policy of the Slovak Republic until 2030 (MENVSR 2020). The Recovery Plan (GOSR 2021) adopted by the Slovak government is a significant legislative and financial incentive to meet these targets as well as to contribute to the ambition of achieving carbon neutrality in the EU by 2050 and reducing greenhouse gases by 2030 by reducing emissions by 55% compared to 1990 declared in NextGenEU (European Commission 2021). The recovery plan is in line with NextGenEU's response to the severe economic downturn due to the COVID-19 pandemic. Its main goal is to support reforms and investments that will enable Slovakia to start catching up with the EU average again, which should be financially supported by approx. €6.5 billion. At the same time, great emphasis is placed on the Green Economy. It is one of the five priority axes in the plan and is expected to get support of over €2.3 billion (GOSR 2021).

Under the Recovery Plan, €62 million should be invested in the modernization of existing facilities of biogas plants and small hydropower plants (GOSR 2021). This can be considered a very prudent step, as the support guaranteeing energy purchase prices for 15 years expires in 2025-2028 for most of the existing biogas plants. Power plants using biogas as a fuel for electricity production will not be competitive after the end of operating support. And although the current rise in fossil fuel energy prices may contribute to the growth of biogas energy competitiveness, the overall rise in commodity prices is also making technologies for renewing or building new biogas plants as well as other plants based on renewable sources more expensive. This reversed the cost reduction trend that the industry has seen for more than a decade (IEA 2021) and showed it still needs financial support.

The aim of the Recovery Plan is therefore to ensure the extension of the life of existing electricity generation facilities, which need additional investments for their further operation. The technological renewal of power plants using biogas as fuel will also be related to the change of the substrate base to biodegradable waste, with the intention of extending their technological life, provided that at least half of the heat produced is used. The transformation of biogas plants into biomethane plants will enable the share of renewable energy production to be maintained by replacing natural gas with biomethane in existing heat and power plants, making full use of the heat produced (GOSR 2021). While in Slovakia the focus on biomethane is more of a vision, in countries such as Denmark and France its production and subsequent distribution to the gas network has been increasing for several years (Gustafsoon and Anderberg 2022)

Today, biogas plants in Slovakia mostly burn agricultural crops, especially corn, only a minority of biogas plants burn waste from agriculture and food. In the future, they should be extended to waste incineration and heat and gas supply. According to the Environment Strategy 2030 (MENVSR 2020), only those biogas plants that will collect sorted biowaste should receive public support. Overcoming these problems should contribute to the further development of energy production from biogas. Integrated National Energy and Climate Plan for 2021 to 2030 (MESR 2019) estimates a gradual increase in the installed biogas capacity from 110 MW in 2020 to 180 MW in 2025 and to 200 MW in 2030. The last figure is already nearing half of the capacity of one Slovak nuclear power plant unit.

Perception of ABPs by operators

All assessed ABPs have guaranteed purchase prices of electricity for 15 years from the start of operation. However, the level of purchase prices decreased from year to year, so previously launched ABPs are guaranteed higher prices than the newer ones. According to ABP operators, profits during the first 8-10 years are very low, due to loan repayments. Only after their repayment expects the ABPs higher profits. However, the economy of ABPs is significantly affected by other factors. The prices of input materials (substrate) have increased over the years, which has increased costs for ABPs and reduced profits. Shipping costs are also important. The greater the distance the substrate is imported, the higher the cost. A specific situation occurred in the case of Veľké Bierovce, where the economy of operation was significantly damaged by several accidents.

In the coming years, the period of guaranteed support for all examined ABPs will end. Therefore, the operators were already addressing the future of their biogas plants at the time of the talks. Two operators have indicated that they are likely to close down (tab. 2). However, their reasons are different. The ABP in Horovce plans to quit operation mainly due to conflicts with the municipality and poor relations with the local population. This shows that the resistance of the population may not only be an obstacle to the establishment of a biogas plant (cf. Martinát et al. 2017, Prosperi, Lombardi and Spada 2019, Dumont, Hildebrandt and Sempuga 2021, Strober et al. 2021), but also an incentive for early decommissioning.

Another case is ABP in Mestečko, the operator argues in favour of decommissioning due to technological wear and high costs of its renewal. The operator sees the potential use of ABP in the transformation into a biomethane station, but the necessary investment would be too large and unprofitable in times of uncertain support from the state. This is similar with the attitudes of other operators who are interested in transforming their ABPs into biomethane plants, but depend on state support mechanisms.

These allegations show that the instability of the support mechanisms is detrimental to investors, with the result that some are considering decommissioning. Such attitudes are actually in line with findings that stability and continuity are among the most important success factors of biogas policies (Kampman, Leguijt and Scholten 2017, Huttunen, Kivimaa and Virkamäki 2014, Ammenberg et al. 2018, Capodaglio, Callegari and Lopez 2016, Dahlgren et al.

2019, Lönnqvist et al. 2019). However, the concerns raised by operators, and the uncertainty, should be dispelled by the Recovery Plan (GOSR 2021), which plans to support investment in the transformation of ABPs into biomethane production. This would bring the use of ABPs in Slovakia closer to Denmark or France (Gustafsson and Anderberg 2022).

The advantage of all examined ABPs is the sugar refinery in Trenčianska Teplá. Beetroot cuttings are a by-product that all ABPs use as a substrate, albeit to varying extent. Of the other substrate components coming directly from the region, the operators highlighted chicken manure from an egg farm and, of course, corn silage. Availability of substrate for energy production in the region is perceived as potential advantage for an ABP operation in the region. However, high concentration of larger ABPs in relatively small area forces operators to import substrates from greater distances, thus increasing operating costs. The exception is ABP in Trenčianska Teplá located directly in the premises of the sugar refinery, from which almost all the substrate comes.

Regarding benefits for local communities, all operators agreed that the direct positive impact of ABPs on employment is small, as ABPs operate with a high degree of automation. Only 1-2 qualified employees and service personnel who supply ABPs with the substrate are sufficient for their operation (tab. 3). This is in line with findings by (Chodkowska-Miszczuk, Kulla, and Novotný 2019) who concluded that, especially in Slovakia, the indirect positive impact of ABPs can also be perceived. ABPs provide farmers with a stable sale of production. This is very important, especially in the country, where post-socialist transformation of agriculture and its competitiveness in common European market is very problematic. However, it can only have an effect if substantial parts of the substrates come directly from the region. Positive indirect impact on employment has ABP Kameničany, which uses heat produced for heating the greenhouses for tomato production, providing jobs mostly for locals (45 employees).

Only the operator of ABP Horovce directly stated that relations with the municipality and the population are bad. He perceives a very strong resistance of the population against the ABP, in addition, the current municipality representatives built a pre-election campaign on the opposition to the plant. Resistance accompanied the project in Horovce from the beginning. The population even organized petitions, but previous representatives of the municipality did not accept them and allowed the operation. The APB operator feels the greatest resistance from residents of nearby apartment blocks. These are the blocks of the former socialist agricultural cooperative, which are in the immediate vicinity of the ABP facilities. Under these conditions, ABP does not actively contribute to community life, nor does it sponsor events or local organizations, although previously they sponsored a local football club.

The communication and attitudes of the population in the planning phase of ABP projects in the other surveyed municipalities were also partly based on the ABP micro-location. The operators in Trenčianska Teplá, Mestečko, and Veľké Bierovce stated that the meetings of the municipal council, where the building permit was approved for ABPs, were peaceful and without problems. To a lesser extent, the residents of Kameničany, whose family houses were located in close proximity to the planned project, expressed disagreement. In particular, they expressed fears of odour, despite the fact that the ABP was being built on the site of a former pigsty. At the initiative of the mayor, the investor organized an excursion to ABP with the same technology in Austria for those interested from Kameničany. All these ABPs support various cultural and social events, sports (football), volunteer firefighters, etc. through sponsorship. In Veľké Bierovce, the operator financially supported the construction of a playground; In Mestečko, the ABP provides fertilizer (digestate) to the local gardeners for free.

***Tab. 3**. Information from interviews with ABPs operators*

	Horovce	Kameničany	Mestečko	Trenčianska Teplá	Veľké Bierovce
Operation and economy					
- profitability	+	+	-	+	-
- substrate supplies	30 km	100 km	12 km	500 m	up to 20 km
- employment	4	3	1	2	4
Relations with the municipality and local population	-	+	+	+	+
Plans with future operation	quit	biomethane production and greenhouses heating	quit	operation as long as the sugar refinery is in operation	biomethane production and possible greenhouses heating

Notes: + stands for "positive/good", - stands for "negative/bad"
Source: Own research conducted in 2018

Perception of ABPs by mayors

From the very beginning of the preparation of the ABP project, it is important to consistently and truthfully inform the population about the benefits and/or risks of this project. Otherwise, distrust arises among the population, which can erupt into resistance to the whole project. It is also necessary to keep the promises given to the municipality and local inhabitants (Wüstenhagen et al. 2007, Rogers et al. 2008, Cowell, Bristow and Munday 2011, Suškevičs et al. 2019, Strober et al. 2021).

Interviews with the mayors show that the residents' reluctance to build ABP appeared already in the preparatory phase in the villages of Horovce, Kameničany, and Slavnica (tab. 4). The main reason, which was also confirmed by the mayors, is the immediate proximity of ABP from residential houses (less than 100 m). In Horovce and Slávnica, these disputes led into several petitions and, in fact, have persisted throughout the existence of the ABP. Relations in Horovce have reached such a position that the municipal council rejects any development project submitted by the ABP operator, or the ABP provocatively exports the digestate and thus causes the smell to spread over the weekends.

Even from the point of view of mayors in the most problematic localities (Horovce and Slávnica), relations between operators and municipalities are at a freezing point. The operation of ABPs is not beneficial for them, the municipalities do not get even the sponsorship of cultural or sporting events, which is a matter of course in other municipalities. Slávnica does not even have increased tax revenues, as APB is located in Kameničany. The mayor in Kameničany also admits tensions between the inhabitants and ABP. Unlike the operator, he does not perceive a significant benefit for employment in the municipality, as there is a low unemployment rate in the region, and only a few people from the municipality are employed in the ABP-heated greenhouses. However, he perceives communication with the ABP operator as fair, he also positively perceives the benefits of taxes and sponsorship of local events. The situation is different in the municipalities of Mestečko, Veľké Bierovce, and Trenčianska Teplá, where the local governments´ relations with the operators are fair. This stems from the mutual trust, the fulfillment of the promises made when the ABP was launched, and the trust that the entrepreneur has among the local population. This confirms the findings of Soland, Steimer, and Walter (2013) that trust in operators has a strong and positive impact on the local acceptance of the ABP.

The location of ABPs is a substantial factor of the level of their acceptance emphasized by several authors (e.g. van den Horst et al. 2018, Donaldson and Lord 2018). In general, the greater the distance from the residential zone, the better the perception. Schumacher a Schultman (2017) identified 1 km as a lower limit of optimal distance. However, ABPs involved in our study (except for the Veľké Bierovce ABP) are located much closer to residential areas. Still, these built-in premises of existing operations are perceived much more positively –

namely ABP in Trenčianska Teplá (within sugar factory) and Mestečko (within operating large farm). ABPs in Horovce and Kameničany are also operating on the premises of large agricultural farms. However, they were abandoned before the ABP was constructed. Therefore, especially for new residents of nearby areas, the launch of the ABP could be a negative new reality.

Despite the diverse experience with the existing ABP, all mayors have stated they support renewable energy production. However, only the mayor of Trenčianska Teplá and partly also the mayor of Veľké Bierovce consider biogas to be a good means. The positive impression of ABP in Veľké Bierovce is quite surprising, as this ABP appeared in media in connection with the explosion in it. The reason is probably the sufficient distance of the ABP from the residential areas and the fair relations between the municipality and the operator. Support for wind energy is more prevalent among the mayors of the affected municipalities.

Tab. 4. *Basic results of interviews with mayors*

	Horovce	Kameničany	Slavnica	Mestečko	Trenč. Teplá	Veľ. Bierovce
Problems associated with the ABP project						
- in the planning phase	Yes	Yes	Yes	No	No	No
- in the operation phase	Yes	Yes	Yes	No	No	No
Local development, benefits for community	No	Yes	No	Yes	Yes	Yes
Attitudes to the RES						
- Support for biogas	No	No	No	Yes	Yes	Yes
- Preferred RES	solar	-	all except biogas	wind	wind	-
Problems linked with the local ABP	location, digestate odour, traffic	location, digestate	location, odour, digestate	none	none	digestate

Source: Own research conducted in 2018

Perception of ABPs by local residents

Both communities in which we examined the social acceptance of local ABP are characterized by potential conflict resulting from the location of ABP extremely close to residential areas. At the same time, there are significant differences between ABPs in installed capacity, heat utilization, and support for local clubs and events. In both cases, the mayors indicated a very sensitive public perception of biogas plants.

Although the operators of both ABPs declared information meetings with the local population before the start of construction of the ABP, the perception of the population rather indicates an insufficient information campaign (fig. 4).

Even less than 10% of the population in Horovce declare the information about ABP they obtained before its construction started was sufficient, while more than two-thirds say it was definitely insufficient. When Kameničany and Slávnica are considered as one community, the results for them are better than for Horovce, but the difference is not substantial. However, the perception is substantially different when Slávnica and Kameničany are evaluated separately. In Slávnica, the sufficiency of information is perceived similarly critically as in Horovce. In Kameničany, more than one-quarter of respondents declared sufficient information and a similar proportion was not able to express if it was sufficient or not. It seems that the mayor's active approach played a positive role in this. On the contrary, when the construction of the ABP just beyond the administrative boundaries of Slávnica took place, the municipality was not directly involved in the project approval process and the population was not adequately informed. At the same time, 45% of respondents expressing a lack of information indicates that the information campaign also had some reserves in Kameničany.

The development of the attitudes toward the ABPs shows that strongly negative attitude towards the ABP project in Horovce in the planning phase even worsened during the operational phase (fig. 5). The negative attitude towards the construction of ABP was even more pronounced in the municipality of Slavnica. However, unlike Horovce, the situation did not worsen after years of operation, and the support even increased very slightly. At present, the negative attitude in Slavnica is not as strong as in Horovce. Even though the negative outweighs, the attitudes in Kameničany are much more balanced and rather stable.

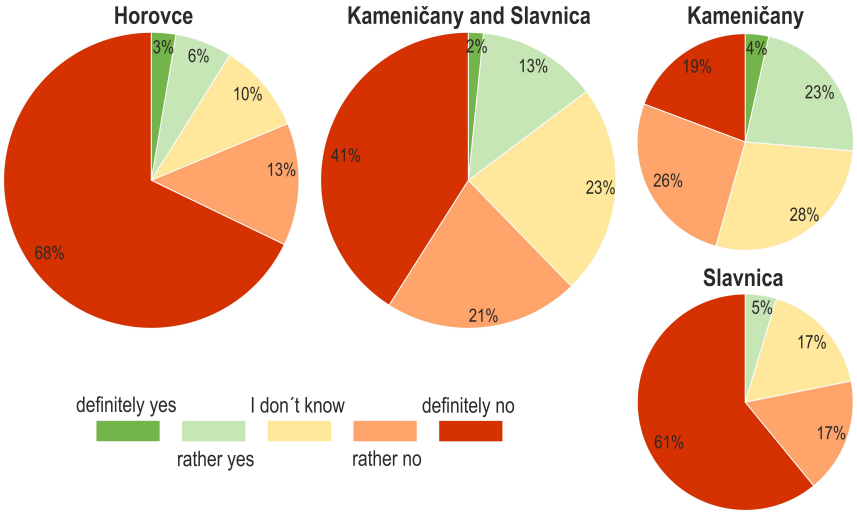

Fig. 4. *Sufficient information about ABP before its construction as perceived by the local population; Source: Own research conducted in 2018*

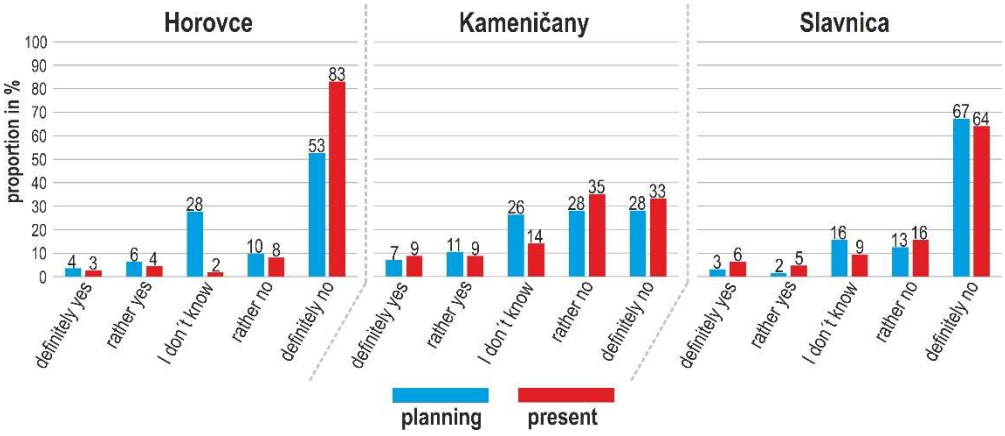

Fig. 5. *Approval for the construction of ABP in the planning phase and at present, with several years of experience with operating ABP; Source: Own research conducted in 2018*

In addition to the mentioned phenomena (location, odor), the research suggests that an important factor in shaping attitudes towards ABP may also be the perception of the extent to which the operator takes serious reservations and objections from the local population. Vast

majority of respondents in Horovce declared the operator does not take their reservations seriously. Such attitudes also slightly prevailed in Kameničany and Slavnica when evaluated together. However, when evaluated separately, respondents from Slavnica showed rather a negative perception but it was much more neutral or positive in Kameničany (fig. 6).

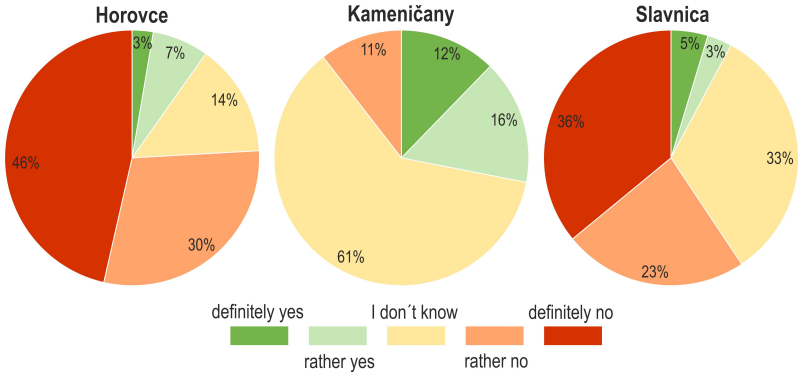

Fig. 6. *Perception if the operator takes the reservations of the local population seriously; Source: Own research conducted in 2018*

Despite many reservations about the operation of ABP in Kameničany and Slavnica, it is clear that its overall perception by the local community is much better than in Horovce. This is especially true for Kameničany, in whose administrative territory ABP is located. Differences in perception are also significantly reflected in the general attitude towards energy produced from biogas. Respondents in Horovce took a significantly negative attitude when it came to supporting the further development and building of ABPs. Nearly two-thirds of them think that ABP should not be built anywhere (fig. 7). In Kameničany and Slavnica, such an attitude is much less represented. The support for building ABPs significantly dominates here, but not in the respondent's community. This seems to be a case of the NIMBY attitude (cf. Bell, Gray and Hagget 2005, Devine-Wright 2005, Warren et al. 2005, Van der Horst 2007, Batel 2020). The support for building new ABPs even in the respondent´s village is stronger in Kameničany than in Slavnica, but the differences are not significant.

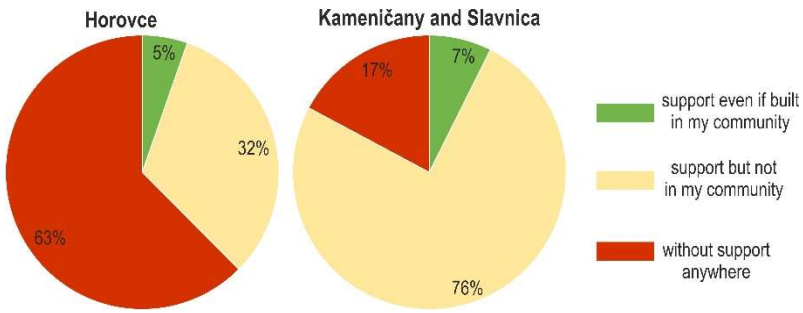

Fig. 7. *Local support for further ABP projects; Source: Own research conducted in 2018*

Our findings support the assumption that the local and personal experience with biogas plant tremendously affects the level of its acceptance. The experience with ABP is primarily case-specific and affected by local socio-cultural context. The lessons learned from our case studies suggest that even if the controversial project is implemented, despite the opposition

of the local community, the level of public confidence in the biogas plant operator has remained low and has significantly affected further project development and overall attitudes towards this form of renewable energy. On the contrary, a well-communicated and planning project and an honest approach to local community reservations can ensure at least a neutral attitude towards ABPs, despite its several critically perceived effects. Residents and municipal representatives' objections towards biogas plants often concern odour and noise. This is also confirmed by our guided interviews and questionnaire survey. However, the application of modern technologies and adherence to the standard substrate and digestate handling should eliminate these side effects. Nevertheless, a suitable location for the station seems necessary. An example of good practice is the Biogas Wien plant, which has been supplying Vienna with thermal energy since 2007 and biomethane from kitchen waste since 2015 (Matiašková and Šoltész 2016).

Conclusions

The countries of the European Union have undergone a significant energy transformation in recent decades. Post-socialist countries in particular, such as Slovakia, must focus on reducing energy dependence on Russia in addition to the decarbonisation goals. The urgency of this transformation increased rapidly after the Russian attack on Ukraine in early 2022. In Slovakia, energy production from biogas has also gained a significant position in this process. As in the case of photovoltaics, the development of the use of this renewable energy source is accompanied by a controversial subsidy policy. State aid originally favoured ABPs with higher installed capacity (around 1MW), which contradicted the original idea of using agricultural waste (especially manure). Therefore, a significant change in the structure of arable crops has begun in favour of green maize in particular, from which the most biogas can be obtained in the ABP. The problem is also that until 2012, when more than half of the currently operated ABPs were already launched, the state did not condition support on the use of the heat produced. In many ABPs, therefore, the heat produced is simply released into the air.

The effects of such policies indirectly contribute to another problem of ABPs, which is their weak public acceptance, especially among the locals. Residents and mayors complain mainly about the smell of BPS, noise, increased traffic in the village as well as improper handling of digestate.

From our point of view, this is due to the reckless placement of ABPs in close proximity to residential areas. Moreover, if the affected population does not benefit from the ABP operation or the promises from the planning phase are not fulfilled, the operation of such a plant is accompanied by constant conflicts. As a result, local residents tend to reject the idea of energy production from agricultural biogas as a whole. Based on controlled interviews with the former and current mayors, ABP managers, and local residents, the following key factors contributing to negative perception were identified:

i. the proximity of the biogas plant, location too close to residential houses,
ii. improper handling with the digestate that causes frequent odour leakages,
iii. unfulfilled promises from the planning phase (e.g. to provide heating for nearby buildings),
iv. increased traffic due to the import of substrate for energy production
v. contamination of drinking water source (the result of the excessive distribution of digestate into the soil),
vi. a political campaign by local officials based on resistance to the ABP.

In contrast, the sharing of benefits from the operation of ABP with the community, appropriate communication, and reflection of complaints of the local population by the ABP operator can contribute to a positive perception of this form of energy production, although the population is critical of some effects of the operation.

These conclusions point to the substantial importance of taking into account social aspects in the preparatory phase of the project. If this is neglected, it can cause failure or reduce the efficiency of a particular operation, and in addition, contribute to the overall negative attitude of the population towards a particular form of renewable energy production. Slovak national policies based on the plans of the European Union envisage further development of energy production from biogas and the transformation of existing biogas power plants into biomethane. Biomethane should subsequently contribute to reducing the consumption of imported natural gas. In this light, the lessons learned from the case studies of various biogas plants are important from a scientific as well as a very practical point of view.

References

AMMENBERG, J., ANDERBERG, S., LÖNNQVIST, T., GRÖNKVIST, S., SANDBERG, T. 2018: Biogas in the transport sector—actor and policy analysis focusing on the demand side in the Stockholm region. *Resources, Conservation and Recycling*, 129, 70-80. DOI: https://doi.org/10.1016/j.resconrec.2017.10.010.

BATEL, S. 2020: Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Research & Social Science*, 68. DOI: https://doi.org/10.1016/j.erss.2020.101544.

BELL, D., GRAY, T., HAGGETT, C. 2005: The 'Social Gap' in wind farm siting decisions: explanations and policy responses. *Environmental Politics,* 14(4)*,* 460-477. DOI: https://doi.org/10.1080/09644010500175833.

BERTSCH, V., HALL, M., WEINHARDT, C., FICHTNER, W. 2016: Public acceptance and preferences related to renewable energy and grid expansion policy: Empirical insights for Germany. *Energy*, 114, 465-477. DOI: https://doi.org/10.1016/j.energy.2016.08.022.

BLUSZCZ, A. 2016: European economies in terms of energy dependence. *Quality & Quantity*, 51, 1531-1548. DOI: https://doi.org/10.1007/s11135-016-0350-1.

CAPODAGLIO, A., CALLEGARI, A., LOPEZ, M. 2016: European Framework for the Diffusion of Biogas Uses: Emerging Technologies, Acceptance, Incentive Strategies, and Institutional-Regulatory Support. *Sustainability*, 8, 298. DOI: https://doi.org/10.3390/su8040298.

CHODKOWSKA-MISZCZUK, J., KULLA, M., NOVOTNÝ, L. 2017: The role of energy policy in agricultural biogas energy production in Visegrad countries. *Bulletin of Geography,* 35*,* 19-34. DOI: https://doi.org/10.1515/bog-2017-0002.

CHODKOWSKA-MISZCZUK, J., KULLA, M., NOVOTNÝ, L. 2019: Biogas energy – A chance for agriculture and rural development? Insight from the post-communist Central Europe. *Deturope,* 11(2), 30-53.

CHODKOWSKA-MISZCZUK, J., MARTINÁT, S., KULLA, M., NOVOTNÝ, L. 2020: Renewables projects in peripheries: determinants, challenges and perspectives of biogas plants – insights from Central European countries. *Regional Studies, Regional Science,* 7(1), 362-381. DOI: https://doi.org/10.1080/21681376.2020.1807399.

COWELL, R., BRISTOW, G., MUNDAY, M. 2011: Acceptance, acceptability and environmental justice: The role of community benefits in wind energy development. *Journal of Environmental Planning and Management*, 54(4), 539-557. DOI: https://doi.org/10.1080/09640568.2010.521047.

DAHLGREN, S., KANDA, W., ANDERBERG, S. 2019: Drivers for and barriers to biogas use in manufacturing, road transport and shipping: a demand-side perspective. *Biofuels*, 13(2), 177-188. DOI: https://doi.org/10.1080/17597269.2019.1657661.

DANIEL-GROMKE, J., RENSBERG, N., DENYSENKO, V., STINNER, W., SCHMALFUß, T., SCHEFTELOWITZ, M., NELLES, M., LIEBETRAU, J. 2017: Current Developments in Production and Utilization of Biogas and Biomethane in Germany. *Chemie Ingenieur Technik*, 94(1-2), 135-144. DOI: https://doi.org/10.1002/cite.201700077.

DEVINE-WRIGHT, P., 2005: Beyond NIMBYism: Towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy*, 8(2), 125-139. DOI: https://doi.org/10.1002/we.124.

DIRECTIVE (EU) 2009/28/EC: Directive 2009/28/ec of the European parliament and of the council of 23 April 2009 on the promotion of the use of energy from renewable sources. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=SK.

DIRECTIVE (EU) 2015/080: A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy. Retrieved from: http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF.

DIRECTIVE (EU) 2018/2001: amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0557.

DIRECTIVE (EU) 2021/550: 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN.

DONALDSON, R., LORD, R. 2018: Can brownfield land be reused for ground source heating to alleviatefuel poverty? *Reneweble Energy*, 116, 344-355. DOI: https://doi.org/10.1016/j.renene.2017.09.037.

DUMONT, K. B., HILDEBRANDT, D., SEMPUGA, B. C. 2021: The “yuck factor” of biogas technology: Naturalness concerns, social acceptance and community dynamics in South Africa. *Energy Research & Social Science*, 71, 101846. DOI: https://doi.org/10.1016/j.erss.2020.101846.

EBA 2016: *AEBIOM Statistical Report 2016*. Brussels (IBTC). Retrieved from: https://ibtc.bioenergyeurope.org/ibtc-demo-report-1/.

EPN 2021: EU measures to guarantee safe and green energy. *EPN – European Parliament News*. Retrieved from: https://www.europarl.europa.eu/news/en/headlines/economy/20210930STO13911/eu-measures-to-guarantee-safe-and-green-energy.

EURACTIVE 2022: *EU puts green label for nuclear and gas officially on the table*. https://www.euractiv.com/section/energy-environment/news/eu-puts-green-label-for-nuclear-and-gas-officially-on-the-table/.

EUROPEAN COMMISSION 2007: *Eurobarometer on Energy Technologies: Knowledge, Perception, Measures*. Retrieved from: https://ec.europa.eu/commission/presscorner/detail/e/MEMO_07_3.

EUROPEAN COMMISSION 2010: *Europeans and Biotechnology in 2010: wind of change?* http://ec.europa.eu/research/science-society/document_library/pdf_06/europeans-biotechnology in-2010_en.pdfS.

EUROPEAN COMMISSION 2021. *The EU's 2021-2027 long-term budget & NextGenerationEU: facts and figures*, European Comission – Directorate-General for Budget Publications. Retrieved from: https://data.europa.eu/doi/10.2761/808559.

EUROSTAT 2022a: Renewable energy statistics: Share of renewable energy more than doubled between 2004 and 2020. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics#Share_of_renewable_energy_more_than_doubled_between_2004_and_2020.

EUROSTAT 2022b: *Nuclear energy statistics. Eurostat – Statistics Explained*. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Nuclear_energy_statistics#Uranium_supply_security.

EUROSTAT 2021a. *Supply, transformation and consumption of renewables and wastes – Indigenous production (Biogases, Landfill gas, Sewage sludge gas and Other anaerobic digestion) 2021*.

EUROSTAT 2021b. *Population on 1 January by age and sex 2021*.

GOSR 2021. *Recovery Plan (Plán Obnovy)*. Bratislava (GOSR – Government Office of the Slovak Republic). Retrieved from: https://www.planobnovy.sk/.

GUSTAFSSON, M., ANDERBERG, S. 2022: Biogas policies and production development in Europe: a comparative analysis of eight countries. *Biofuels.* DOI: https://doi.org/10.1080/17597269.2022.2034380.

HUNTER, S., LEYDEN, K., 1995: Beyond NIMBY. Explaining opposition to hazardous waste facilities. *Policy Studies Journal*, 23(4), 601-619. DOI: https://doi.org/10.1111/j.1541-0072.1995.tb00537.x.

HUTTUNEN, S, KIVIMAA, P, VIRKAMÄKI, V. 2014: The need for policy coherence to trigger a transition to biogas production. *Environmental Innovation and Societal Transitions*, 12, 14-30. DOI: https://doi.org/10.1016/j.eist.2014.04.002 .

IEA 2021. What is the impact of increasing commodity and energy prices on solar PV, wind and biofuels? *International Energy Agency Analyses.* Retrieved from: https://www.iea.org/articles/what-is-the-impact-of-increasing-commodity-and-energy-prices-on-solar-pv-wind-and-biofuels.

JANČURA, M., PROZBÍK, J. 2019: Jadrová energia a CO2. *Bencont Weekly Report*, 24, 1-4.

JANIŠ, S. 2014. Bioplyn na Slovensku, definitívny koniec? *oEnergetike.sk.* Retrieved from: http://www.oenergetike.sk/oze/bioplyn-na-slovensku-definitivny-koniec/.

JANÍČEK, F., NÉMETHOVÁ, J., PERNÝ, M., ŠÁLY, V. 2017: Current status and potential of biomass utilization in the Slovak Republic. *Waste Forum*, 9(5), 418-426.

JANÍČEK, F., PERNÝ, M., ŠÁLY, V., NÉMETHOVÁ, J. 2018: Biogas Stations in Slovakia - Current State. *Transactions on Electrical Engineering*, 7(4), 79-85. DOI: https://doi.org/10.14311/TEE.2018.4.079.

JENČOVÁ, I. 2021: Slovakia suddenly a frontrunner in renewable energies. *Euractive.sk*. Retrieved from: https://www.euractiv.com/section/politics/short_news/slovakia-suddenly-a-frontrunner-in-renewable-energies/.

KAMPMAN, B., LEGUIJT, C., SCHOLTEN, T. et al. 2017: *Optimal use of biogas from waste streams - An assessment of the potential of biogas from digestion in the EU beyond 2020*. Luxembourg (European Commission).

KORTSCH, T., HILDEBRAND, J., SCHWEIZER-RIES, P. 2015: Acceptance of biomass plants – Results of a longitudinal study in the bioenergy-region Altmark. *Renewable Energy*, 83, 690-697. DOI: https://doi.org/10.1016/j.renene.2015.04.059.

KULLA, M., NOVOTNÝ, L., PREGI, P., DVOŘAK, P., MARTINAT, S., KLUSÁČEK, P., NAVRATIL, J., KREJČÍ, T., FRANTÁL, B. 2022: The good, the bad, and the nobody: Exploring diversity of perceptions of anaerobic digestion plants in Central and Eastern Europe. *Energy Research & Social Science,* 89, 102644, DOI: https:// doi.org/ 10.1016/j.erss.2022.102644.

LÖNNQVIST, T., ANDERBERG, S., AMMENBERG, J., SANDBERG, T., GRÖNKVIST, S. 2019: Stimulating biogas in the transport sector in a Swedish region – An actor and policy analysis with supply side focus. *Renewable and Sustainable Energy Reviews*, 113, 109269. DOI: https://doi.org/10.1016/j.rser.2019.109269.

MAGNANI, N. 2012: Exploring the Local Sustainability of a Green Economy in Alpine Communities. *Mountain Research and Development*, 32(2), 109-116. DOI: https://doi.org/ 10.1659/MRD-JOURNAL-D-11-00105.1.

MARTINÁT, S., NAVRÁTIL, J., TROJAN, J., FRANTÁL, B., KLUSÁČEK, P., PASQUALETTI, M. J. 2017: Interpreting regional and local diversities of the social acceptance of agricultural AD plants in the rural space of the Moravian-Silesian Region (Czech Republic). *Rendiconti Lincei*, 28 (3), 535-548. DOI: https://doi.org/10.1007/s12210-017-0628-9.

MARTINÁT, S., CHODKOWSKA-MISZCZUK, J., KULLA, M., NAVRÁTIL, J., KLUSÁČEK, P., DVOŘÁK, P., NOVOTNÝ, L., KREJČÍ, T., PREGI, L., TROJAN, J., FRANTÁL, B. 2022: Best Practice Forever? Dynamics behind the Perception of Farm-Fed Anaerobic Digestion Plants in Rural Peripheries. *Energies*, 15, 2533. DOI: https://doi.org/10.3390/ en15072533.

MATA PÉREZ, M. E., SCHOLTEN, D., STEGEN, K. S. 2019: The multi-speed energy transition in Europe: Opportunities and challenges for EU energy security. *Energy Strategy Reviews*, 26, 100415. DOI: https://doi.org/10.1016/j.esr.2019.100415.

MATIAŠKOVÁ, L., ŠOLTÉSZ, J. 2016: Vývoj a súčasný stav budovania bioplynových staníc v SR. *Energieportál*. https://www.energie-portal.sk/Dokument/vyvoj-a-sucasny-stav-budovania-bioplynovych-stanic-v-sr-103375.aspx.

MENVSR 2020: *Greener Slovakia – Strategy of the Environmental Policy of the Slovak Republic until 2030*. Bratislava (MENVSR – Ministry of Environment of the Slovak Republic). Retrieved from: https://www.minzp.sk/files/iep/publikacia_zelensie-slovensko-aj_web.pdf.

MESR 2010: *National Action Plan for Energy from Renewable Sources*. Bratislava (MESR – Ministry of Economy of the Slovak Republic). Retrieved from: https://energy.ec.europa.eu/document/download/578b30a8-d594-451b-9ff5-0072941ce3ef_en.

MESR 2019: *Slovakia's Integrated National Energy and Climate Plan for 2021 to 2030*. Bratislava (MESR – Ministry of Economy of the Slovak Republic). Retrieved from: https://ec.europa.eu/energy/sites/ener/files/sk_final_necp_main_en.pdf.

MESR 2021: Končí sa stop-stav na pripájanie nových zdrojov na výrobu elektriny, budeme mať viac zelenej energie. *MESR press news*. Retrieved from: https://www.economy.gov.sk/top/konci-sa-stop-stav-na-pripajanie-novych-zdrojov-na-vyrobu-elektriny-budeme-mat-viac-zelenej-energie.

MICIUŁA, I., WOJTASZEK, H., WŁODARCZYK, B. et al. 2021: The Current Picture of the Transition to a Green Economy in the EU—Trends in Climate and Energy Policy versus State Security. *Energy*, 14, 8181. DOI: https://doi.org/10.3390/en14238181.

PPCA 2020. Slovakia coal phase-out. *The Powering Past Coal Alliance (PPCA) online news*. Retrieved from: https://www.poweringpastcoal.org/about/who-we-are.

PROSPERI M., LOMBARDI M., SPADA, A. 2019: Ex ante assessment of social acceptance of small-scale agro-energy system: A case study in southern Italy. *Energy Policy*, 124, 346-354. DOI: https://doi.org/10.1016/j.enpol.2018.10.015.

REGULATION (EU) 2018/1999 *of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action*, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council. Retrieved from: http://data.europa.eu/eli/reg/2018/1999/oj.

REGULATION (ÚRSO) No. 221/2013 *of the regulatory authority ÚRSO to set the prices for energy*. Retrieved from: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2013/221/.

ROGERS, J. C., SIMMONS, E. A., CONVERY, I., WEATHERALL, A. 2008: Public perceptions of opportunities for community-based renewable energy projects. *Energy Policy*, 36(11), 4217-4226. DOI: https://doi.org/10.1016/j.enpol. 2008.07.028.

RÖDER, M. 2016: More than food or fuel. Stakeholder perceptions of anaerobic digestion and land use; a case study from the United Kingdom. *Energy Policy,* 97, 73-81. DOI: https://doi.org/10.1016/j.enpol.2016.07.003.

SEGRETO, M., PRINCIPE, L., DESORMEAUX, A. et al. 2020: Trends in Social Acceptance of Renewable Energy Across Europe - A Literature Review. *International Journal of Environmental Research and Public Health,* 17(24), 9161. DOI: https://doi.org/10.3390 /ijerph17249161.

SCHUMACHER, K., SCHULTMANN, F. 2017: Local Acceptance of Biogas Plants: A Comparative Study in the Trinational Upper Rhine Region. *Waste Biomass Valor,* 8, 2393-2412. DOI: https://doi.org/10.1007/s12649-016-9802-z.

SITA 2022. Pokročil povoľovací proces spustenia tretieho bloku v Mochovciach (Advanced permitting process for the start of the third unit in Mochovce). *SME Ekonomika*. Retrieved from: https://ekonomika.sme.sk/c/22827166/pokrocil-povolovaci-proces-spustenia-tretieho-bloku-v-mochovciach.html.

SOLAND, M., STEIMER, N., WALTER, G. 2013: Local acceptance of existing biogas plants in Switzerland. *Energy Policy*, 61, 802-810. DOI: https://doi.org/10.1016/j.enpol.2013. 06.111.

SOSR 2022: *Energy – Annual publication for 2006-2020. Energy balance in the SR – Table No. 4-4-4: Production Capacity of Electricity and Liquid Biofuels*. Bratislava (SOSR – Statistical Office of the Slovak Republic).

SUŠKEVIČS, N. B., EITER, S., MARTINAT, S., STOBER, D., VOLLMER, E., DE BOER, C. L., BUCHECKER, M. 2019: Regional variation in public acceptance of wind energy development in Europe: What are the roles of planning procedures and participation? *Land Use Policy*, 81, 311-323. DOI: https://doi.org/10.1016/j.landusepol.2018.10.032.

STROBER, D., SUŠKEVIČS, M., EITER, S., MÜLLER, S., MARTINÁT, S., BUCHECKER, M. 2021: What is the quality of participatory renewable energy planning in Europe? A comparative analysis of innovative practices in 25 projects. *Energy Research & Social Science*, 71, 101804. DOI: https://doi.org/10.1016/j.erss.2020.101804.

TORRICHOS, M. 2016: State of Development of Biogas Production in Europe. *Procedia Environmental Sciences*, 35, 881-889. DOI: https://doi.org/10.1016/j.proenv.2016.07.043.

UPRETI, B. R., VAN DER HORST, D. 2004: National renewable energy policy and local opposition in the UK: The failed development of a biomass electricity plant. *Biomass Bioenergy*, 26(1), 61-69. DOI: https://doi.org/10.1016/S0961-9534(03)00099-0.

VAN DER HORST, D. 2007: NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies. *Energy Policy*, 35(5), 2705-2714. DOI: https://doi.org/10.1016/j.enpol.2006.12.012.

VAN DER HORST, D., MARTINAT, S., NAVRATIL, J., DVORAK, P., CHMIELOVA, P. 2018: What can the location of biogas plants tell us about agricultural change? A Case Study from the Czech Republic. *Deturope*, 10(1), 33-52.

WARREN, C. R., LUMSDEN, C., O'DOWD, S., BIRNIE, R. V. 2005: "Green on Green": public perceptions of wind power in Scotland and Ireland. *Journal of Environmental Planning and Management*, 48(6), 853-875. DOI: https://doi.org/10.1080/09640560500294376.

WNN 2021. New nuclear reactor will make Slovakia a power exporter. *World Nuclear News (WNN)*. Retrieved from: https://www.world-nuclear-news.org/Articles/New-nuclear-reactor-will-make-Slovakia-a-power-exp.

WÜSTENHAGEN, R., WOLSINK, M., BÜRER, M. J. 2007: Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), 2683-2691. DOI: https://doi.org/10.1016/j.enpol.2006.12.001.

ZOELLNER, J., SCHWEIZER-RIES, P., WEMHEUER, CH. 2008: Public acceptance of renewable energies: Results from case studies in Germany. *Energy Policy*, 36(11), 4136-4141. DOI: https://doi.org/10.1016/j.enpol.2008.06.026.

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