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Article

Conversion of Post-Socialist Agricultural Premises as a Chance for Renewable Energy Production. Photovoltaics or Biogas Plants?

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Abstract: We aim to contribute to in-depth comprehension of the factors and preferences behind the reuses of large-scale underused or abandoned former collective farms from the 1950s–1980s for biogas plants and solar photovoltaic power plants. As a case study, three regions in the southern part of the Czech Republic have been selected. Our findings signal that the residents' attitudes towards the mentioned energy sources are rather negative. Similarly, farmers' interest in photovoltaic power plants is low. More interest has been detected in the case of biogas production; this is especially true for large agricultural companies and farmers, who own underused or abandoned premises. Biogas plants are frequently located in agricultural areas with warmer or just slightly colder climates as a consequence of the potential to process locally grown maize. On the other hand, photovoltaic power plants are found on more fertile plains with high levels of insolation, but, surprisingly, also in mountain regions which typically have low emissions. Both renewable energy solutions were found to be problematic as there is strong opposition to both types of installations among local inhabitants. This indicates the need for "soft" forms of planning. Stakeholder engagement and inclusive participation in all phases of the planning process are essential requirements for arriving at the best possible outcomes for the new renewable energy solutions and their acceptance by the public.

Keywords: post-socialistic; brownfield; agriculture; transition; renewable energy

1. Introduction

To respond to the challenge of climate change, global greenhouse gas emissions urgently need to be reduced [1,2]. United Nations' Sustainable Development Goal 7 (SDG7) recommends a substantial increase of the share of renewable energy (RE) in the global energy mix to ensure access to affordable, reliable, sustainable, and modern energy. European Union (EU) climate policies also define the share of energy to be produced from renewable resources and require member states to meet these targets [3,4]. The Czech Republic is no exception, and as one of the highest producers of CO_2 per capita in the EU, urgently needs to transform its energy systems onto a sustainable pathway [5].

Unfortunately, the potential for wind energy, especially in comparison with coastal Atlantic states, is negligible in the Czech Republic; likewise hydrothermal energy [6]. Moreover, there is almost no potential to expand hydropower beyond existing capacity [7]. Thus, biogas plants and solar photovoltaic (PV) power plants are important options for the Czech Republic, even though, in the case of PV, geographical conditions are not optimal.

Both of these options for the RE production are directly linked to the rural environment. Agriculture in these countries has undergone a major transformation in the last three decades [8], leading to many underused or abandoned sites (Figure 1) potentially suitable for the installation of PV or biogas installations [9].

Figure 1. Typical view of an abandoned cowshed, part of a former collective farm. Image by Tomáš Krejčí (Borová Lada, the Czech Republic, 21 October 2020).

For the reasons described, the importance of using these two RE sources is undeniable. On the other hand, the construction of biogas plants and, in particular, PV installations, poses a significant risk of losing good agricultural land [10]. In Central Europe, high-value agricultural land is often lost in this way, leading to a deterioration in the image of these sources of clean energy. In this sense, the use of dilapidated agricultural buildings and their surrounding areas is a unique opportunity for the construction of both biogas and PV plants, since these tend to be under-valued, more marginal, or under-utilized agricultural areas.

In this paper, we aim to contribute to the understanding of the potential of former collectivized agricultural areas in post-socialist countries for sustainable energy production using the example of biogas plants and PV installations. Henceforward we refer to these areas, including land or buildings, as “collective farms”.

2. Background and Hypotheses

2.1. The Origins of Unused Agricultural Premises

Since the early 1950s, large-scale agricultural premises were built for local agricultural production in almost every village under the “one village, one farm” communist agricultural model promoted in the Soviet Union [11]. These new premises, popularly known as “collective farms”, drastically changed the design of Czech villages creating new centers of rural life.

Dramatic changes in the utilization of communist agricultural premises quickly followed the Velvet Revolution (1989), going hand in hand with the restructuring of the whole agricultural sector caused by the process of restitution and privatization of land and premises after 1991. Substantial reduction in government subsidies to agriculture after 1993 led to further changes. Economically ineffective organizational structures of communist agricultural companies, major changes in land ownership, the inflow of cheap food imports, and the general decline in agricultural production led to large numbers of underused agricultural premises (Figure 1) [12].

2.2. Renewable Energy on Unused and Derelict Sites

Previous studies have analyzed a diverse spectrum of potential reuses for abandoned agricultural premises [13,14]. Environmentally friendly reuses aligned with sustainability principles would be beneficial [15,16], since former uses were enormous sources of pollution in rural areas. RE production, even if temporary, is, therefore, one of the most desirable ways to reuse such sites [17,18]. Unused and derelict agricultural sites have clear potential for rapid RE development [19] providing an important opportunity to solve two challenging environmental problems: (i) the introduction of RE production in rural areas, (ii) and to support remediation of derelict and/or contaminated rural sites [20]. Brownfield sites that have been successfully regenerated for RE production in this way have been referred to as "brightfields" [21]. In the literature, RE uses with the highest potential on such sites were found to be: (i) the production of biofuels or biogas [22], (ii) solar PV and wind farms [23], and (iii) geothermal energy [24]. Brownfield PV, in particular, was identified in several studies as an accessible alternative for marginalized communities lacking access to rooftop space [25] as an economically viable solution in post-industrial regions [26] and as a means to alleviate fuel poverty [27] in rural populations.

For this reason, in the socio-economic and environmental context of the Czech Republic, PV and biogas plants seem to be the most promising RE production systems [10]. However, the expansion of both of these RE types has previously been heavily dependent on substantial subsidies from the national government and the EU [28], e.g., for PV in 2009–10 and biogas in 2011–13 [29,30].

The reuse of derelict sites for RE production in the Czech Republic is therefore still quite rare [31], though, in the case of PV there has been some previous experience [32]. Analysis of the location of PV plants with a production capacity > 1 MWp has shown that circa 10% of their area is located on previously abandoned areas including mines, industrial enterprises, and agricultural premises [10]. Analyses of different new uses of collective farms identified several localities with PV plants (Figure 2) [33]. Biogas plants were built predominantly in rural space by large-scale farmers [29,30,34] and often in close proximity or directly within the boundaries of collective farms (Figure 3) [33].

Figure 2. PV plant on the site of a former cowshed. Image by Tomáš Krejčí (Chvalatice, the Czech Republic, 15 May 2021).

Figure 3. Biogas station on part of the area of a former collective farm. Image by Tomáš Krejčí (Chlumec near Dačice, the Czech Republic, 4 June 2021).

2.3. Preferences of Residents for Development of Photovoltaic Power Plants and Biogas Plants

The acceptance of different RE systems by the population varies substantially [35,36] because each type of RE has different physical characteristics [37,38] and, consequently, differing impacts on particular localities [39]. While public attitudes to RE have been found to be generally positive in many countries [40,41], the physical presence of specific installations is often perceived rather negatively, or at least controversially [42]. This is true for both PV and biogas plants [43].

In Central European countries the acceptance of biogas production has been studied specifically in rural areas [44]. Many studies record a negative perception of biogas plants by inhabitants of rural communities [43]. Diverse reasons for this negative perception include a perceived reduction of the quality of the local environment (including odor leakages) or in reduced attractiveness of the local area for tourism [45]. The image of biogas production was further tarnished by their identification with the environmentally questionable practice of supplying such plants with energy crops that were purpose-grown on good arable land [46].

For the case of PV plants, public perceptions are mixed. While small-scale PV installations on the rooves of houses are rather positively perceived [47], large-scale on-ground systems (solar farms) tend to be negatively perceived [48,49]. A major public controversy has arisen from several cases of large, publicly-funded on-ground privately-developed solar farms, whose owners have remained unknown. It has been speculated that these developments are secretly owned by politicians who previously authorized the public funding [35]. On the other hand, there is less contextual public opposition to brightfields compared to conventional RE on greenfield sites [21,50]. This leads us to our first hypothesis:

Hypothesis 1a. *Preferences for PV and biogas plants are different, depending on where they are located.*

Environmentally conscious behaviors, attitudes, perceptions, or intentions have been shown to differ by rural population group [51,52]. Gender, age, and education were shown to be among the most important factors influencing preferences for particular RE systems.

Previous studies also suggested that females are more environmentally conscious and more open to environmentally sustainable solutions than males [53,54]. Gender was also found as a factor in determining preferences for different RE systems [55–57]. Age has also been shown to be responsible for the differences in pro-environmental inclinations [58] that depend on the type of RE system in question. Compared to gender, the influence of age influence seems to be less consistent, and in most cases, age-related preferences were not confirmed by all studies [53,59–61]. Educational level was also found to influence preferences for different types of energy production systems [62,63]. These findings lead us to our next two hypotheses:

Hypothesis 1b. *Preferences for photovoltaic power stations are not uniform throughout the population.*

Hypothesis 1c. *Preferences for biogas plants are not uniform throughout the population.*

2.4. Farmers' Interest in the Development of PV and Biogas Plants

Local inhabitants are usually not those who finance the building of PV and biogas plants. On former collective farms, the financing for such schemes depends on the landowners or tenants. Their level of interest in RE is therefore crucial for the development of such installations [64].

As a result of particular interest by Central European policymakers in biogas production [45], large-scale governmental subsidies together with a long term-guaranteed purchase price of generated electricity made available, resulting in the very rapid development of anaerobic digestion (AD) plants [28]. As a result, biogas installations spread quickly throughout the countryside and, by the end of the first decade of the 21st century, it had become one of the most productive types of RE in the Czech Republic [29]. The capacity of these AD plants is usually larger than the waste available on-farm that could be processed and farmers frequently found it easier to grow crops specifically to feed their biogas plants [64]. This combination of factors led biogas plants to become one of the most profitable agricultural businesses [30]. For many farmers, the loss of subsidies for biogas production will lead to the bankruptcy of their farms [64].

As noted earlier, PV plants also offered opportunities for diversification of Czech farms through RE [10]. As with biogas, governmental subsidies also led to a PV boom [28]. At the moment, on-ground PV plants cover more than four thousand hectares of agricultural land as a result of a poorly designed support policy. This issue is also heavily discussed in the Czech media and has significantly affected the perception of on-ground solar power plants in the Czech Republic [10,35]. On the other hand, PV rooftop installations remain popular. Nowadays, new PV plants are rare as subsidies are less attractive than before. This leads us to our next hypothesis:

Hypothesis 2a. *The level of interest in PV plants is different from that of biogas plants.*

As different RE systems can be operated with various levels of profitability according to the macro- and microeconomic situation of individual farms, the level of interest among farmers differs significantly as well. Previous studies show substantial differences in preferences for different RE systems especially among farms of differing sizes and production foci [64]. This rationale is behind the next hypotheses:

Hypothesis 2b. *The degree of interest in the financing of PV plants is influenced by the type of owner.*

Hypothesis 2c. *The degree of interest in the financing of biogas plants is influenced by the type of the owner.*

In-depth analyses of the former, current, and planned uses of former collective farms [65] showed that there are strong ties between the former, present, and future potential uses of such premises [9]. This is especially the case for premises that have already been recently adapted for other new uses. Logically, the level of interest in making further adaptations for RE production would be lower. Our next hypothesis states that:

Hypothesis 2d. *The history of (re)use of premises can influence the degree of interest in the financing of PV plants.*

Hypothesis 2e. *The history of (re)use of premise can influence the degree of interest in the financing of a biogas plant.*

Based on all previously mentioned circumstances it can be assumed that there are differences among preferences of local inhabitants and the level of interest of farmers in developing PV or biogas plants. So our next hypothesis is as follows:

Hypothesis 2f. *Preferences of local inhabitants may not accord with landholders' interests in developing RE plants.*

2.5. Current Spatial Consequences of PV and Biogas Plants on Former Collective Farms

Many PV and biogas plants have already been installed throughout the Czech countryside [10,11,29,34,45,64,66,67], and there is no doubt that in many cases they are located on former collective farms [33].

The location of PV plants is partly, but not entirely, dependent on solar resource potential [68]. The influence of the solar resource turns out to be less important than the design of the policy [10] and ultimately, the decisions made by individual farmers [64]. On the other hand, the spatial distribution of agricultural biogas plants on former collective farms would be expected to be random since such farms are ubiquitous [33]. However, such plants also need to be close to their feed sources, i.e., locations of waste from crop or dairy production. Indeed, for diverse agricultural and socio-economic reasons, their distribution is in fact, not random, as previously detailed analyses have shown [12,65]. This assumption leads us to our final hypothesis:

Hypothesis 3. *There are differences in the localization of PV and biogas plants on former collective farm sites.*

3. Materials and Methods

3.1. Study Area

Three neighboring regions, South Moravia, South Bohemia, and Vysočina (EU NUTS level 3) located in the southern part of the Czech Republic, was selected as a case study area, (Figure 4). The case study area can be considered representative of the aim of the study as it covers almost one-third of the area of the Czech Republic. Moreover, the selected regions encompass all main agricultural production areas, ensuring adequate coverage of the diversity of agricultural and socioeconomic conditions found in the Czech Republic as a whole. Within the study area, excellent natural conditions for crop production can be found, mainly located in the lowlands of South Moravia, where typical crops include grapes, corn, sunflower, and sugar-beet. On the contrary, the highlands of Vysočina are especially known for the cultivation of wheat and potatoes.

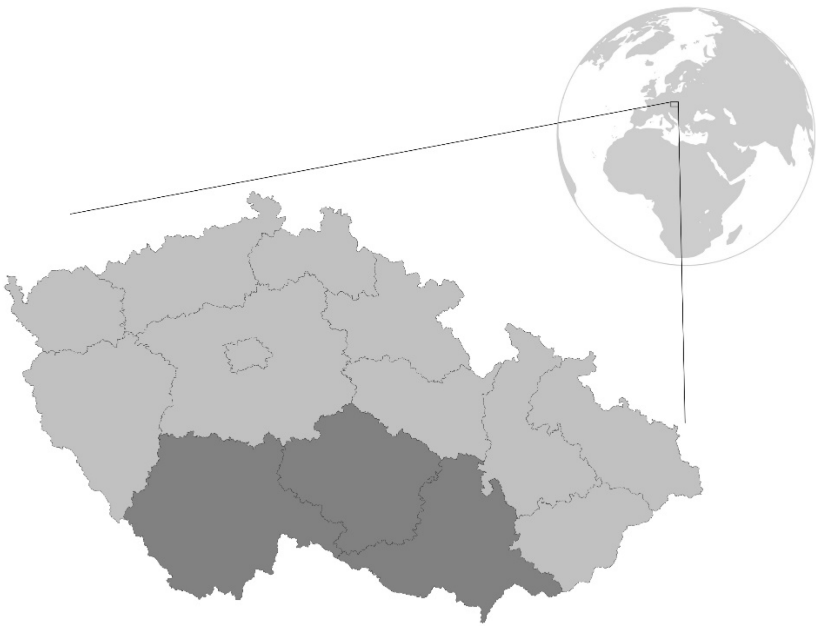

Figure 4. The area under study.

3.2. Data Collection

Due to the complex nature of our research, three different types of data were needed to achieve our aim and validate or reject the hypotheses proposed. These are—information about (i) use preferences of inhabitants of rural communities for former collective farms; (ii) the reuse preferences of owners of these premises; and (iii) the location of all the premises and their present potential use for PV or biogas production (Figure 5).

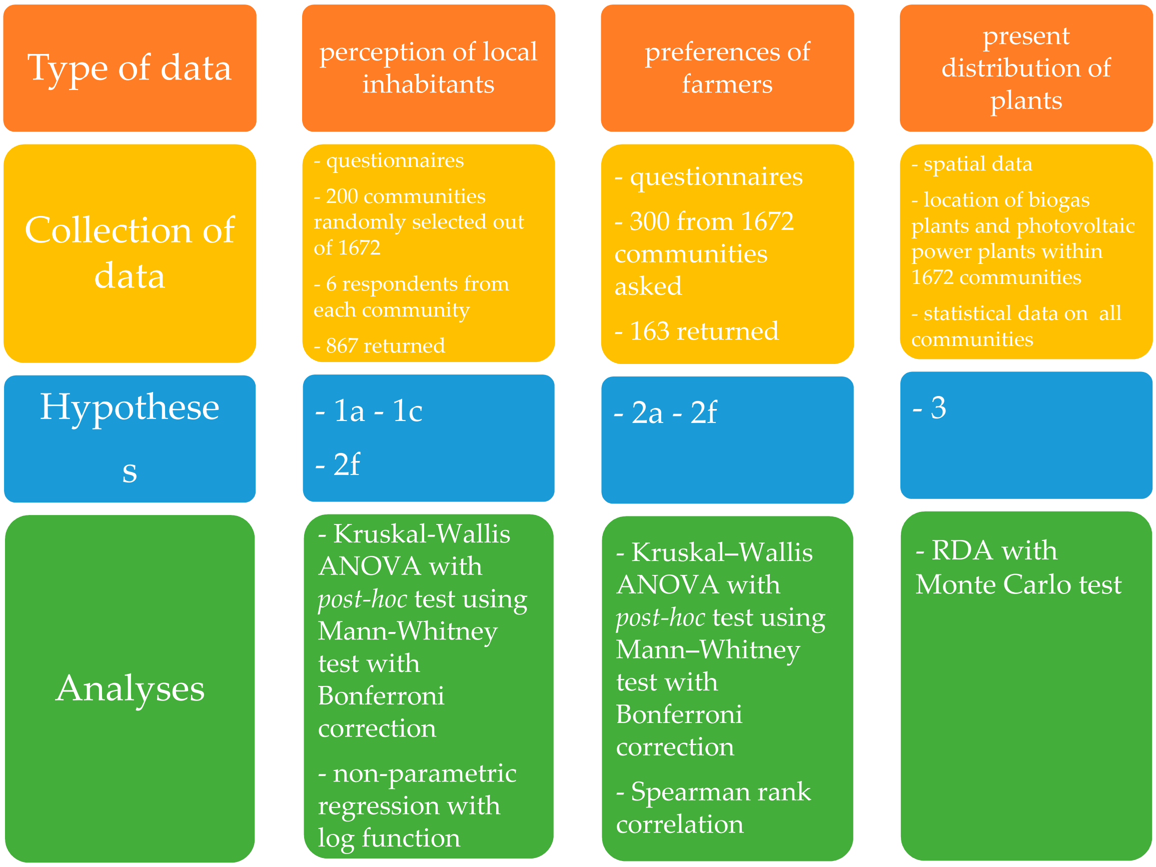

Figure 5. Research strategy.

3.2.1. Use Preferences of Inhabitants of Rural Communities for Former Collective Farm Sites

Use preferences of inhabitants were collected through a questionnaire survey of 200 communities where collective farms were present. The communities were selected at random from a previously existing database of 1672 communities with collectivized agricultural premises dating to the communist era before 1989 [65,69].

Six respondents aged 18 years or over, with their place of residence in the community of interest, and with the knowledge about the existence of former collective farms in that community, were approached in each of the selected communities. To ensure gender and age diversity of respondents, three females and three males in each of three age categories (18–40 years of age, 40–60 years of age, and >60 years of age) were asked to complete the questionnaire. In total, 1200 respondents were addressed and answers were obtained from 867 respondents resulting in a 27.75% refusal rate. The fieldwork was carried out between July and August 2020. The respondents were approached by the researchers on the streets of individual communities. The questionnaires were completed with the help of interviewers, who explained the aim and purpose of the study. The anonymity of individual interviewees was ensured, and all participants agreed to be part of the research. Individual questionnaires were completed in ca. 10 min. All participants provided contact details to the researchers so that clarifications could be requested later if needed.

The questionnaire comprised of two questions regarding the perception of potential reuses of collective farm sites for PV or biogas plants. The respondents were asked to indicate their degree of preference for each type of reuse. Preferences were measured on a five-point Likert scale where one indicated strong disagreement and five indicated strong agreement.

Questions regarding the demographic and socio-economic status of respondents were located in the second part of the questionnaire. They included gender, age measured in years as a ratio variable, level of education measured as a multinomial variable in six categories, and economic status measured as a multinomial variable in six categories.

3.2.2. Preferences of Farmers (Owners or Tenants of Former Collective Farm Sites)

Reuse preferences of the owners of former collective farms were also randomly selected in the same way from the above-mentioned database (but independently). Altogether, 300 farmers were selected. A printed questionnaire was sent out to their addresses by regular mail and was available, farmers were also contacted by email, or by telephone during the second half of February 2019. The farmers from whom a reply was not obtained were visited in person during April and May 2019. Finally, 163 questionnaires (46.6% refusal rate) were returned for analysis.

The first part of the questionnaire was the same as the questionnaire for inhabitants. Two questions regarding the preferences for PV or biogas plants were asked. Then, main information regarding the type and size of the farms were collected—(i) size of the area of cultivated land, number of cattle, and number of employees, and (ii) the experience with ownership/tenancy of unused and/or derelict agricultural premises.

3.2.3. Differentiation in Present Uses of Former Collective Farm Sites for PV and Biogas Plants

As a basis for our analyses carried out to answer hypothesis 3 (differences in locations of PV and biogas plants on former collective farm sites), we used the spatial distribution of these premises from the database described in Section 3.2.1 [65,69].

PV and biogas plants within the borders of former collective farms were identified from aerial images of the Czech Republic freely accessible from the web map services (WMS) of the Czech Office for Surveying, Mapping, and Cadastre (WMS—Orthophoto: https://geoportal.cuzk.cz/WMS_ORTOFOTO_PUB/WMService.aspx, accessed on 10 September 2021). The aerial imagery used was captured in 2018 and 2019. All localities were then verified by panoramic imagery available via the website application Mapy.cz and the street view function of Google Maps. The suitability of such a procedure has been demonstrated in an earlier study [33].

Four types of municipalities were defined on the basis of the presence of PV or biogas plants: (i) municipalities with PV plants on the area of former collective farms, (ii) municipalities with biogas plants on the area of former collective farms, (iii) municipalities with PV and biogas plants on the area of former collective farms, (iv) municipalities without PV or biogas plants on the area of former collective farms.

To understand the socio-economic context of these four types of communities, socio-economic and environmental data were obtained from the Czech Statistical Office (Table 1). Data from the 2011 Census [70] and other data [71] were both used. The average price of agricultural land in Czech Crowns, based on Regulation no. 298/2014 [72] was also used. Agricultural production areas (Corn AAP, Sugar-beet AAP, Grain AAP, Potato AAP, and Fodder crop AAP) were sourced from previous studies [73].

Table 1. Data used as independent variables in the testing of Hypothesis 3 (data on communities).

Variables Used	Code in Figure	Source
Share of population with maximum primary education (2011) (%)	PriEdu	[70]
Share of population with a university education (2011) (%)	UniEdu	[70]
Share of the economically active population working in agriculture, forestry, and fisheries (2011) (%)	PriEco	[70]
Share of the native population (2011) (%)	Native	[70]
Number of newly-built houses (2019)	Houses	[71]
Share of recreation houses of total houses (2019) (%)	Recre	[71]
Population number (2019)	Pop	[71]
Population change 2019/2009 (%)	PopCh	[71]
Share of population younger than 15 years (2019) (%)	Up15	[71]
Share of the population older than 65 years (2019) (%)	Ab65	[71]
Age index (2019)	AgeInd	[71]
Average age (2019)	AvAge	[71]
Coefficient of ecological stability (2019)	CoEco	[71]
The average basic price of agricultural land	Price	[72]
Share of agricultural land of total area (2019) (%)	Agri	[71]
Share of arable land of agricultural land (2019) (%)	Arable	[71]
Share of pastures and meadows of agricultural land (2019) (%)	Meadow	[71]
Share of water surfaces of total area (2019) (%)	Water	[71]
Share of forests of total area (2019) (%)	Forest	[71]
Share of built-up areas of total area (2019) (%)	Built	[71]
Location in Agricultural production area—Grain	Grain	[73]
Location in Agricultural production area—Potatoes	Potatoes	[73]
Location in Agricultural production area—Fodder crops	Fodder	[73]
Location in Agricultural production area—Corn	Corn	[73]
Location in Agricultural production area—Sugar-beet	SugarB	[73]

3.3. Data Analyses

As data regarding perception of PV and biogas plants among inhabitants and landholders were measured using the same questions, Hypotheses 1a, 2a, and of course 2f, were tested together. Since response data were not normally distributed, the hypotheses were tested using Kruskal–Wallis ANOVA with a *post-hoc* Mann–Whitney test with Bonferroni correction (for further details see e.g., [74]). Violin plots (see e.g., [75]) were used to visualize the distribution of the answers.

Non-parametric regression with log function was used to test Hypotheses 1b and 1c (testing of the potential impact of gender and socio-economic characteristics of inhabitants on preferences for photovoltaic power plants and biogas plants). Preferences for photovoltaic power plants and biogas plants were used as dependent variables and gender, age, education level, and economic status were used as independent predictors. As only statistically important predictors were of interest, forward selection of independent variables for regression was used [74,76].

To test our Hypotheses 2b and 2c (ties between characteristics of farms and preferences for photovoltaic power plants and biogas plants) we used Spearman rank correlation [74] among degrees of interest in the financing of PV or biogas plants and all three farm size variables (area of cultivated land in hectares, number of animals calculated in cattle units, number of employees).

Kruskal–Wallis ANOVA with *post-hoc* Mann–Whitney test with Bonferroni correction was used to test Hypotheses 2d and 2e (potential differences in preferences for PV and biogas plants among four types of farms according to their experience with abandoned/derelict premises).

To test our final Hypothesis 3 (differences in location of PV and biogas plants on collective farm sites), spatial data were used. The aim was to test for spatial relationships between the current presence of PV and plants on collective farm sites on the one hand, and environmental, social, and economic characteristics of the communities on the other. Four types of communities (see Section 3.2.3) and statistical data for all communities (Table 1) were used. Previous studies have suggested that communities are best seen as a continuum of differences, rather than as discrete types. The aim was therefore to find a statistical relationship between the structure of communities' characteristics and the presence of PV and/or biogas plants. As there are many variables (25 in our case) describing the communities, multivariate techniques are suitable to test this hypothesis. The regression of the presence or absence of PV and/or biogas plants on the structure of characteristics of communities was done by redundancy analysis (RDA) (see [77] or [78]). The potential dependence of presence or absence of PV or/and biogas plants on the structure of characteristics of communities was carried out using a Monte Carlo permutation test [77,78] which compares the structure of real data and the structure of randomly arranged values of the same data [79]; 999 random permutations were used [80].

Violin plots were prepared using the vioplot package in R [75]. RDA calculations were carried out using CANOCO 5.0 software [77,78]. Regression calculations and other tests were performed in Tibco Statistica software (ver. 13.3) [81].

4. Results

4.1. Preferences for Photovoltaic Power Plants and Biogas Plants by Residents

Preferences for PV and biogas plants on former collective farm sites are low among local inhabitants for both types of installation (Hypothesis 1a). The median value for biogas plants (dark blue in Figure 6) is 2 and for PV plants (green in Figure 6) is even lower (1). This difference is statistically significant (multiple comparisons using Mann–Whitney test with Bonferroni correction after Kruskal–Wallis test, $p < 0.05$).

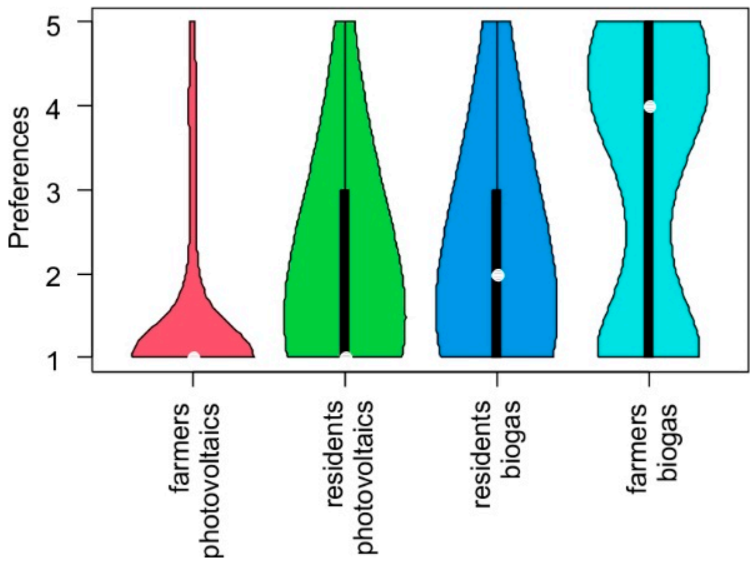

Figure 6. Preferences of local inhabitants and the degree of interest of residents and landholders in developing PV and biogas plants.

Preferences for PV plants among local inhabitants (Hypothesis 1b) are significantly influenced by gender, age, and level of education as shown by the regression analysis (Table 2). Higher preferences for photovoltaic power plants are found among younger people, males, and inhabitants with a higher level of education (Table 3).

Table 2. Results of the regression model—residents, PV plants.

	d.f. [1]	Likelihood Type 3 Test Log-Likelihood	Chi-Square	p
Intercept	1			
Age	1	−1286.26	6.625	0.010
Gender	1	−1285.96	6.033	0.014
Education	1	−1285.21	4.534	0.033

[1] d.f. = degrees of freedom.

Table 3. Estimates of parameters—residents, PV plants.

	Estimate	S.E. [1] of Estimate	Wald Stat.	p
Intercept	0.632	0.076	70.053	0.000
Age	−0.003	0.001	6.878	0.009
Gender (male)	0.048	0.020	6.053	0.014
Education	0.032	0.014	4.819	0.028

[1] S.E. = standard error of mean.

Out of our measured independent variables, preferences for biogas plants among local inhabitants (Hypothesis 1c) are significantly influenced only by the level of education (Table 4). As was the case for PV plants, stronger preferences for biogas plants among the inhabitants are found in individuals with a higher level of education (Table 5).

Table 4. Results of the regression model—residents, biogas plants.

	d.f. [1]	Likelihood Type 3 Test Log-Likelihood	Chi-Square	p
Intercept	1			
Education	1	−1378.23	6.116	0.013

[1] d.f. = degrees of freedom.

Table 5. Estimates of parameters—residents, biogas plants.

	Estimate	S.E. [1] of Estimate	Wald Stat.	p
Intercept	0.589	0.050	141.366	0.000
Education	0.036	0.014	6.404	0.011

[1] S.E. = standard error of mean

4.2. Interest of Farmers in PV and Biogas Plants

Compared to the results of preferences of residents, the degree in interest in PV and biogas plants is very diverse among farmers owning or renting former collective farm sites (Hypothesis 2a). The median value is very high (4) for biogas plants (turquoise in Figure 5) but very low (1) for PV plants (pink in Figure 5). This difference is significant (multiple comparisons using Mann–Whitney test with Bonferroni correction after Kruskal–Wallis test, $p < 0.001$).

Preferences of local inhabitants for PV and biogas plants are significantly different from the degree of interest of farmers (Hypothesis 2f) in these types of technology (Figure 5). All four medians differ significantly (multiple comparisons using Mann–Whitney test with Bonferroni correction after Kruskal–Wallis test). Neither group of respondents were interested in PV plants—the interest of farmers is even lower than the preferences of local inhabitants ($p < 0.001$). On the other hand, the difference in preferences between farmers and local inhabitants is large in the case of biogas plants ($p < 0.001$). Biogas plants are disliked by local inhabitants, yet clearly of great interest to farmers.

Farmers' interest in PV plants (Hypothesis 2b) is negatively influenced by the area of land a farmer has under cultivation (Table 6). Farms with larger areas of cultivated land are less interested in PV plants. There is no significant correlation between the level of interest in PV installations and the number of animals calculated in cattle units or the number of employees. This means that farmers who oppose PV plants tend to be engaged in crop production rather than livestock farming. The opposite is true for biogas plants. The interest in biogas plants of farmers is positively influenced by the area of land a farmer has under cultivation and the number of employees they have (Table 6). The bigger the farm, the greater the interest in biogas plants.

Table 6. Spearman rank correlation for interest in PV and biogas plants and variables regarding the size of the farm. * $p < 0.05$; ** $p < 0.01$.

	Photovoltaics		Biogas	
area of the farm	−0.21	**	0.15	*
number of farm animals	n.s.[1]		n.s.[1]	
number of employees	n.s.[1]		0.17	**

[1] n.s. = not significant.

Then the potential impact of owning unused or abandoned premises on interest in PV plants was tested (Hypothesis 2d), but no correlation was found (Kruskal–Wallis test: H (3, N = 163) = 2.369394, $p = 0.4994$).

On the other hand, farmers in different situations with respect to abandoned collective farm premises (demolished, never owned, own now, or have reused) did show significant diversity of interest (Kruskal–Wallis test: H (3, N = 163) = 20.08726, $p = 0.0002$). Those who reused formerly abandoned premises were significantly less interested in biogas plants (Hypothesis 2e) (Figure 7).

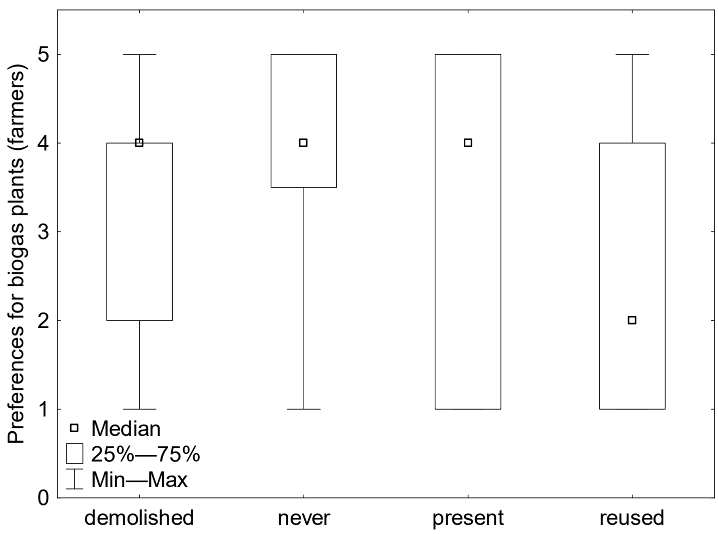

Figure 7. Boxplot of interest in biogas plants according to the owning of an abandoned premise.

4.3. Spatial Impacts on Development of PV and Biogas Plants Former Collective Farm Sites

Our last Hypothesis 3 was tested by RDA. This multivariate technique revealed significant connections between the structure of characteristics of municipalities and the current presence of PV and/or biogas plants as the first and all canonical axes are significant (first axis: pseudo-F = 1.2, $p = 0.015$; all axes: pseudo-F = 1.7, $p = 0.029$; Figure 8a).

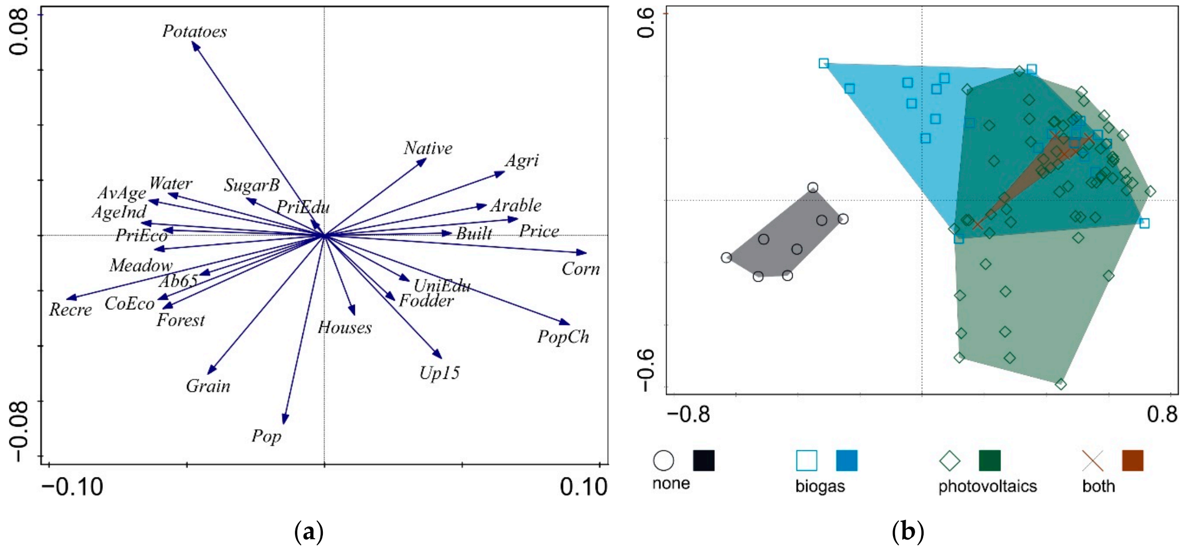

Figure 8. (**a**) Ties among significant characteristics of communities in two-dimensional RDA space; (**b**) Position of four types of communities under investigation in the same space.

According to the position in two-dimensional ordination space, we can conclude that biogas plants (biogas in Figure 8b) are more often located in areas with higher shares of agricultural land, higher shares of the native population, but also with greater shares of second homes. They are located in two different agricultural areas—corn production areas with the best preconditions for crop production and potato-producing upland areas. PV plants on former collective farm sites tend to be located in larger communities with younger and better-educated populations especially in corn production areas, but also in fodder-crop production areas where pastures dominate at the highest elevations. Communities, where both PV and biogas plants are located in intermediate RDA space, are primarily those in areas with high shares of arable land. These tend to be large rural municipalities within corn agricultural production areas where land prices are high—effectively the most productive agricultural areas of the Czech Republic.

5. Discussion

Our analysis of the possibilities offered by former collective farm sites for RE development offers two key lines of discussion: (i) RE production in agricultural landscapes and (ii) differences in attitudes around RE development between inhabitants and owners.

5.1. Renewable Energy Production in Agricultural Landscapes

Renewable energy production in agricultural landscapes is a key issue because the installation of PV and biogas plants needs land, sometimes in quite large amounts [10]. The impact of RE developments on specific agricultural areas is, therefore, an important consideration in landscape planning [82].

Biogas plants were more frequently located in agricultural areas with forage production, especially corn silage, and this was the case in both warmer and slightly cooler areas. PV plants were mainly located in two types of areas: (i) fertile lowlands with high insolation and (ii) in mountain areas with negligible pollution levels—in this latter type, we note that these are areas with limited possibilities for innovative use of agricultural land. There is no doubt that these kinds of landscapes are being transformed by RE developments, with both positive and negative consequences, and it is necessary to help PV and biogas development transition to more environmentally and socially sustainable models.

One solution may be to encourage RE developments on abandoned or degraded land, e.g., brownfield sites. Research from the USA [1] has suggested that demand for RE at a regional level could be met by such sites. Similarly, Jurgutis et al. [83] see the reclamation of abandoned arable land as a possible strategy for biomass generation. Site selection characteristics for PV or biogas developments have been examined by several authors [29, 84]. These kinds of developments can lead to significant changes in rural landscapes, which can, in some cases be completely transformed (e.g., Chodkowska-Misczuk et al. [43]). Walker [85] perceived that these transformations lead to contradictory perceptions of RE by the population. Land management is a key issue for biogas and PV developments. Dias et al. [86] highlight the importance of ensuring the compatibility of PV developments with land-use activities, e.g., agriculture and forestry and nature conservation. Planning procedures should take environmental impacts and public perception into account, not just the economic dimension of developments [85]. However, the extent to which sustainability criteria and compatibility with other land uses are included in land management procedures varies across countries and regions. The consumption of agricultural land by PV and biogas plants is a key issue of concern. Pascaris et al. [87], stress the need to preserve 'agricultural interests' in green energy development. Without these kinds of thoughtful approaches to siting and compatibility with existing uses, building widespread support for RE developments in rural communities is likely to remain difficult.

Yet, it is clear that without social acceptance by the wider public, the energy transition cannot succeed. To avoid a state of perpetual tension between agriculture and energy land-uses, a mutually beneficial relationship must be purposefully sought [87]. A positive public attitude towards renewables is necessary at all stages of development—planning, implementation, and operation. Bevk and Golobic [88] note that RE projects are frequently implemented in the face of resistance from local communities, despite renewable energy being very positively perceived by the public. This may be due to the fact that RE projects are frequently carried out almost in secret, with very little information, if any, provided to local communities in advance of development. Indeed, Soland et al. [89] suggest that the growth of positive attitudes towards new energy sources locally (specifically agricultural biogas plants) is closely linked precisely to the provision of good (credible) information at the planning stage of the installation itself. Thus, when deciding the siting of RE developments, a combination of many different factors needs to be taken into account (see e.g., [90]), with the scale of the proposed development being one of the most important considerations [62,91].

5.2. Preferences for Renewable Energy Solutions: Inhabitants vs. Owners

Generally, the image of renewable energy is positive [43]. On the other hand, the construction of PV, and especially biogas plants is often problematic because of local community opposition [45]. The results of our survey confirm that the popularity/acceptance of at least some renewable energy types among the population is generally at a very low level. Their attitude can—to put it mildly—be characterized as reticent, and in some places, one can speak directly of aversion or negative attitude towards the development of biogas and PV plants. However, there is a difference in this perception between the (non)acceptance of PV and biogas plants on the sites of unused agricultural areas. In both cases, the conversion to energy use is more positively accepted by the population in direct proportion to increasing levels of educational attainment [62]. In addition, PV developments are more strongly supported by males than females, and by younger people.

As we have noted, green energy development has not been systematically approached in the Czech Republic. This may explain the varying levels of acceptance among the rural populations surveyed. In the case of PV, the negative image is already associated with the first stage of PV development, which started around 2009. The PV construction boom was a response to the strong financial support available for PV developments, in particular, the guarantee to buy back the energy produced under very generous conditions (in the context of Law 180/2005). Of course, state support for RE is not specific to the Czech Republic. It has been a very significant driver of RE expansion in many other countries [1,92–94]. However, in the Czech case, the poor policy design has led to almost mafia-like practices in the development of PV installations. This fact still resonates strongly with the public, which feels that the system has been designed to favor specific private companies and that the generous feed-in-tariffs have been paid for by individual citizens through high energy prices. Moreover, in this first stage of construction, PV resources were built almost exclusively on greenfield sites, with no use of brownfield sites or otherwise disadvantaged areas. The encroachment of these developments on agricultural land can be considered as a second important reason for the negative perception of PV, which is typical especially for the older population (partly also those with lower education). Many local people agree with farmers on this issue. Among farmers, support for PV is also low, with the lowest levels of support found among owners of farms with crop production—which is probably due to experience with PV construction on agricultural land. However, Frantál and Prousek [64] point out in this context that Czech farmers often declare their opposition to the construction and use of RE plants, while operating them! Thus, the impacts of PV construction on the landscape may not be unequivocally negative in real life (e.g., [91] or [95]). The construction of the biogas plants has also experienced a similarly rapid development to the PV plants. Here, we can also note the poorly designed policy for their overall development and role in the energy mix. The development of this type of renewable energy has also met with resistance from the population. Martinat et al. [29] have categorized this first phase of biogas development as "resulting in unintended environmental consequences and missed opportunities to enhance energy self-sufficiency and resilience in the countryside" (the same can be said for the development of PV). On the positive side, biogas plants developed in the first phase were mainly concentrated in less favorable agricultural areas, which were difficult to use otherwise.

Analyzing the reasons for the negative attitude towards biogas energy development, there are contradicting views, especially around the kinds of resources that should be processed. In fact, in the Czech Republic, primary agricultural production is often used rather than biowaste. Linked to this is the view of opponents of biogas that land is being taken out of use for food production (either for livestock or for further processing in the food industry). The idea of growing crops solely for 'burning' has led to negative perceptions of the whole process and is seen, to some extent as a threat to the food supply or even national food security. The cultivation of energy crops (mainly corn) to supply biogas plants has not only increased significantly in the Czech Republic in recent years, but the same trend is also evident in other European countries. In Germany, it is confirmed, for example, by Lüker-Jans et al. [96], who also document a significantly associated decline in permanent grassland areas.

However, the situation is changing. For many years now, the use of livestock waste [97] or residual bio-waste has been discussed and implemented in the field of biogas plant material, which is increasing in importance in connection with the technological development of new generations of AD plants. This is confirmed, for example, by Chodkowska-Miszczuk et al. [44], who in their study demonstrate the significant and increasing benefits of biowaste treatment in Poland, both from agricultural production and households (although they see it as partly unintentional). Dobers [92] stresses that diversification of raw materials used for biogas production can be an important factor in improving their acceptance by the population. Thus, the use of bio-waste has significant potential to improve the sustainability of biogas production. Moreover, according to experiences from Wales (UK), biogas plants using waste are more evenly spatially distributed compared to those processing agricultural crops [98]. The higher acceptability of such a solution is also demonstrated by the results of our research among farm owners. Farmers show considerable interest in the construction of biogas plants. At the same time, this interest is greater the larger the size of their farm (in terms of both area and number of employees; this direct relationship is confirmed by Frantál and Prousek [64]). Higher support for the construction of biogas plants is also declared by those farmers who have unused buildings on their premises that have not undergone major reconstruction. Thus, the implementation of a biogas energy source is an interesting incentive for them to (i) increase the value of the property (also in view of the expected increase in energy prices), (ii) attain energy self-sufficiency, or (iii) improve economic development and economic sustainability (in the sense of circular economy). The latter may not only affect the farm itself but have a wider impact on the locality. For example, Dvořák et al. [28] note the benefits of biogas development for employment in rural areas, albeit limited by the level of financial incentive for these sources. Further positives can be anticipated with the technological development of biogas plant facilities—at a minimum, the removal of odor from their operation will, according to Soland et al. [89], highlight the positive benefits derived from this type of energy and increase public acceptance. The expansion of energy production in rural areas would potentially mean the export of its surpluses and thus could also benefit the local population. Poggi et al. [90] thus see an even more prominent role for rural municipalities in shaping the next renewable energy development strategy.

6. Conclusions

Spacious underused and abandoned former collective farms dating to the socialist period (the 1950s–1980s) innumerable in the rural space of post-socialist Central Europe. This is especially true in the Czech Republic, where nearly 97% of agricultural land was collectivized during the early 1950s and independent farmers effectively ceased to exist. This phenomenon has had enormous consequences for the management of land up to the present day. As the need to tackle climate change grows more urgent, the role of agriculture and rural and farmland areas needs to be more seriously considered. Decentralized renewable and sustainable energy systems have important potential to reduce the carbon footprint of agriculture. In the socio-economic context of the Czech Republic, PV and biogas plants are among the most promising RE systems to be introduced on these large-scale post-agricultural sites.

We have found that residents' attitudes towards both RE types are very negative. Highly educated residents were the most interested in both types of RE. Farmers' interest in photovoltaic energy was also surprisingly very low. This is especially the case for arable farms. This is probably related to the fear of encroachment of PV plants on productive farmland, something that is unfortunately quite common. On the other hand, farmers' interest in biogas production is significantly higher; this is especially true for large farms and the owners of underused or abandoned premises.

Where former collective farm sites had been reused for PV or biogas installations, a diverse spatial pattern was detected. Biogas plants tend to be located in agricultural areas suitable for corn growing in warmer and moderately cold areas. Conversely, PV plants could be found more frequently on fertile plains with high insolation but also in mountain regions with low emissions. It seems that the two types of RE systems tend to be situated in quite different agricultural areas. Communities where both biogas plants and photovoltaic power plants are usually located in areas sharing characteristics commonly favored by both types.

The PV plants in former collective farm areas are thus generally at a very low level and its further development is hampered by extremely low interest from investors and very low interest from the local population. In contrast, the development of biogas plants is at a much higher level due to subsidies. There is a higher level of interest among farmers, but this is met with opposition to biogas energy from the local population.

Several implications for energy planning and land management emerge from the results of our research presented here. The two types of green energy production are perceived significantly differently by the local population and potential investors. There is low interest in photovoltaics among both groups, due to their overall very poor image associated with subsidy scandals for their construction and the negative environmental impacts associated with building large-scale plants on the best arable land in the Czech Republic. It will be very difficult to restore this reputation, and the mere renewal of subsidies for their construction is unlikely to change the reluctance of the local population to accept them. Our research has also confirmed the diametrically opposed attitude of the population and farmers toward biogas plants. Conflicts have always accompanied their construction and operation, and they will continue to do so if current policy and planning approaches are maintained. The spatial dependence on the geographical conditions follows from the location of the implemented reuses.

Our research leads to some key policy recommendations. Planning for RE in rural areas must overcome many obstacles. The planning process must assume a diversity of attitudes towards new installations. Both RE types were found to be problematic as there is strong opposition among local inhabitants to each of them. "Soft" aspects of planning need to be considered. Local opposition could be overcome with inclusive participation. Stakeholder engagement and inclusive participation in all phases of the planning process are essential requirements for increasing public acceptance of RE projects and achieving high-quality outcomes from their installation.

The limitations of our study are mainly related to the small size of the Czech Republic and the specific context of development during the period of collectivization and after the fall of the Iron Curtain. The European dimension is needed and for further research aimed at cross-cultural differences in acceptance and interest of RE among rural communities.

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