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Research paper

It's not right, but we do it. Exploring why and how Czech farmers become renewable energy producers

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ABSTRACT

The paper provides empirical evidence on emerging on-farm renewable energy enterprises in a post-communist space, namely in the Czech Republic. In addition to exploring farmers' individual motivations to adopt activities related to renewable energy production (biofuel crops growing, biomass production, operation of anaerobic digestion (AD) plants, and implementation of solar and wind energy projects), the study focuses on analysing regional and inter-firm variances in the level and types of adopted activities. A considerable discrepancy between stated personal attitudes of farmers (supporting the traditional view that farmers should only produce food) and actual practice of farms (dealing with renewable energy production for economic reasons) was detected. The extent and types of energy activities proved to be influenced both by geographical conditions and types of farm. While there are significant differences between the studied districts with different climatic and geographic conditions in the type and extent of energy crops and biomass cultivation, the expansion of AD plants and solar power systems was observed the same in both areas. The adoption of energy activities is positively correlated with company size and area of cultivated land, and negatively correlated with the degree of focus on livestock production. While growing biofuel crops is typical for large and medium-sized enterprises, individual farmers and small enterprises with less land area are more likely to produce biomass for combustion and use own grounds and roofs for implementing solar systems. Finally, the most common four types of currently adopted multipath renewable energy enterprises were identified.

1. Introduction

> "If subsidies for biogas energy were abolished, I would kill pigs and stop doing this business"
>
> (Manager of agricultural AD plant)

Agriculture has a dual role as an energy user and as an energy supplier, notably by producing biomass and bioenergy. This energy productive function has been recently highlighted and promoted – particularly within the European Union (EU) countries – as an opportunity for economic diversification and development of rural areas as well as for enhancing energy sustainability, energy security, and mitigating global climate changes [1,2].

As a result of regulations, production quotas and subsidies promoted under the EU's Common Agricultural Policy (CAP) and Energy Policy, many farmers have adopted new business models to diversify and stabilize their businesses, including organic farming, direct marketing, agro-tourism and renewable energy (RE) production activities [3]. Various crops are preferably cultivated to generate electricity and fuel cars, the energy from biogas produced in agricultural anaerobic digestion plants (hereinafter AD plants) became for many companies an essential additional source of income to keep the farming business going [4,5]. Thousands of hectares of quality farmland have been covered by solar panels, and farmers became owners of significant share of wind energy projects in some regions [6,7].

The policy support and development of agro-energy business has altered the land use dynamics, brought about new land use conflicts [8] and disconnections between policy makers and stakeholders [9,10]. Other unintended environmental and societal consequences include changes of landscape (e.g., visual intrusion by wind turbines and solar panels, landscape yellowfication due to the wide-spreading cultivation of oil seed rape), soil-erosion and deforestation [11], and concerns about food price increase and food insecurity [12].

While the literature is quite vast as concerns farmers' attitudes towards agricultural restructuring and diversification trends in general [13–17] or particularly as far as their willingness to grow

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energy crops and biomass [18–22] it seems to be much more limited as concerns other emerging RE enterprises. Only in recent years the first few studies investigated the scale of adoption of AD plants, solar and wind power technologies by farmers [23–25]. Majority of these studies (actually almost all come from the UK or the US) focused in particular on behavioural and cognitive factors, which affect the adoption (or potential adoption) of RE activities by farmers, their stated motivation factors and perceived barriers.

The contribution of this paper to the current knowledge about the diffusion and adoption of on-farm RE enterprises is represented by three aspects: (i) it is the first empirical evidence on the issue from the post-communist space, which is characterized by some specifics compared to the rest of Europe; (ii) it covers all forms of RE related activities run by farmers, including biofuel crops growing, biomass and biogas production, and solar and wind power plants; (iii) in addition to exploring farmers' individual attitudes to the transformation of agriculture and their motivation factors to adopt new technologies, we focus on analysing the regional and inter-firm variance in the extent and types of RE enterprises currently carried out by Czech farmers.

The research questions that drive the study were defined as follows:

- What are the attitudes of Czech farmers to the traditional productive role of agriculture and the development of on-farm RE enterprises?
- What is the current real rate of adoption and most common types of RE enterprises adopted by Czech farmers?
- Are the rate and forms of involvement in RE enterprises differentiated with respect to climatic and geographic conditions, and the type, size, and production focus of farms?
- What are main motivation factors and barriers affecting the adoption of RE enterprises as perceived by farmers?

Our study was not, however, aimed primarily at absolute numbers concerning the overall level of adoption of energy producing activities but rather at exploring specific relative indicators and relationships between factors.

2. Development of on-farm renewable energy enterprises: literature overview

In 1981, a new *Energy in Agriculture* journal was launched reflecting on new challenges in the context of ongoing technological and energy transitions [26]. Although the journal's primary focus has been on the effective use of energy IN agricultural production, the potential of agricultural sector FOR energy generation has been emphasized from the first issue. More than thirty years later, the agro-energy business developed into so many shapes and scales that then authors could hardly have imagined.

At the beginning of a new millennium, most papers [15,27–29] on farmers' willingness to diversify their activities in the context of CAP reforms have reported about prevailing conservative attitude, which claimed that farmers should only produce food and fibres. However, the more recent studies [23,24,30] detected a significant increase in the production of biomass and biofuel crops and in the adoption of other RE enterprises by farmers. This could have been caused by both the liberalization of farmers' opinions, intensifying competition in the market, and/or robust economic incentives to boost RE development.

According to a classical definition by Rogers [31] the innovation diffusion is a process by which an innovation is communicated through certain channels over time among the members of a social system. While the diffusion process takes place at the level of the social system, the innovation-adoption process takes place at the level of individuals or groups, and is linked with the decision-making process. The spatial diffusion of on-farm renewable energy innovations is not determined just by the optional or collective decisions by farmers; it has specific features and objective (geographical, technical or legislative) limits. A significant factor for on-farm RE development is also social acceptance of projects (particularly those with distinct impact on local landscape and life quality, such as wind turbines or biogas plants) by local communities [32,33].

Nevertheless, sometimes institutional interventions (directives, subsidies) and the human factor (individual motivation) may put over these limits. Recent studies on the 'solar business boom' in East-Central Europe [34–36] have detected that the spatial pattern of implementation of large photovoltaic plants in many countries does not correlate with the spatial distribution of solar resource potential. The result is that more PVs were constructed in regions with insufficient solar potential but with cheap land. This demonstrates that the energy policy and equal subsidies may be inefficient and that their design open the door to many individual investment decisions that are not necessarily in the best public or landscape interest. Similarly, the opponents of agro-energy development have stressed it is just a contrived, subsidy-driven business whose forms (e.g., the type and extent of cultivated crops) do not adequately respect geographic prerequisites and the need of sustainable soil cultivation and landscape stewardship.

A key influence of economic drivers was reflected in most studies on the potential for adoption of RE enterprises. Surveys on the adoption of solar, wind and AD plants in the UK [25,30], short-rotation coppice in Sweden [37] or biomass production in Greece [38] have come to similar results concerning the predisposition of farmers to run new enterprises. Potential adopters are more likely to have larger farm businesses, be owner occupiers, younger and better educated than non-adopters. Study on the potential of switchgrass production among Tennessee farmers [19] revealed that farmers with above average on-farm incomes were less enthusiastic to switchgrass production, while those with above average off-farm incomes were more ready to adopt the new crop.

A detailed analysis of the adoption of wind and solar energy technologies by Californian farmers [23] reported about significant differences in the types of farms adopting an off grid, small residential, small commercial or large commercial systems. A very distinct divide was found particularly between the adopters of commercial and non-commercial installations. They also underline the importance of evaluating the choice of the size (capacity) adopted in addition to the technology adoption choice. One study from the UK [30] analysed the diffusion of different RE enterprises in time. However, so far no study (if authors know) has analysed the influence of geographical factors on the extent and types of energy related activities run by farmers.

3. Geographical context of the study

Farming in the Czech Republic – as an example of post-communist countries - has experienced significant structural changes since the socio–political transition after the break of socialism in 1989 [39]. A centrally planned economy has changed to market economy with large consequences for agricultural sector, which had previously been one of the most supported branches of communist era, and during last two decades it has been facing a dynamic decline of its productionist focus [40]. Selected indicators of the agricultural transformation and expansion of technical crops and technologies used for renewable energy production are presented in Table 1.

As a result of historical development (the processes of expropriation of land and collectivization of farms during the communist era), the Czech agricultural sector is still characterized by specifics regarding the size structure of farms and the proportion of owned and leased land. While the average area of utilized land per holding

Table 1
Selected indicators of structural changes in Czech agricultural sector.

Indicator	1989	2004	2009	2014	Change (%) 1989–2014
Number of employees (thousands)	533	137	120	104	- 80
Share of employment in agriculture (%)	10.3	4.1	3.1	2.7	- 73
Number of pigs (million)	4.686	3.127	1.971	1.617	- 66
Sowing area of potatoes (km^2)	1150	360	290	240	- 79
Sowing area of cereals (km^2)	16,700	16,070	15,280	14,110	- 16
Sowing area of maze for grain (km^2)	240	880	920	1000	+317
Sowing area of industrial sugar beet (km^2)	1270	710	520	630	- 50
Sowing area of rape (km^2)	1020	2590	3550	3890	+281
Number of agricultural AD plants	3	8	133	388	+12,833

Notes: The total area of the Czech Republic is 78,866 km^2. Year 1989 is the last year of communist state regime; Year 2004 is the year of entry into EU. Source of data: Czech Statistical Office [41], Czech Biomass Association [42], and authors' calculations.

in EU was about 15 ha, it is about 150 ha in the Czech Republic. While the proportion of land owned by farmers within EU-15 was about 50%, the proportion of owned land in the Czech Republic is only about 20%. While small agricultural entrepreneurs (natural persons) represent about 85% of all agricultural holdings (in total about 22,000), they have only 30% of utilized agricultural land. All these aspects affect the relationship of farmers to the land and its commercial exploitation.

Approximately 60% of the total agricultural area in the Czech Republic belongs to less favoured areas (LFA) category, about 13% of agricultural land is located in mountain areas with very unfavourable mountain conditions, and approximately 8% is located in protected areas with specific environmental restrictions [43]. These factors significantly limit conventional agricultural production. On the other hand, the common composition of agricultural areas is quite suitable for alternative agricultural production, in particular biomass production [43,44]. Continual reductions in purchase prices of most products (either crops, meat or milk) due to a competitive pressure from agriculturally 'stronger' countries (e.g., Germany, Netherlands, Poland) caused the redemption prices do not cover even the cost of planting and breeding. As a result, farmers have been changing the focus of their production and they seek other sources and ways of income, such as direct marketing, agro-tourism and utilization of land for energy crops growing or for implementation of RE technologies.

Currently about 20% of all arable land is used for planting of industrial crops, majority of which is represented by rape (about 400,000 ha). Rape is the dominant crop for producing fatty acid methyl esters (FAMEs) used as biodiesel. In 2014, the production of rape reached 1537 million tonnes, of which about one third was used for the production of biodiesel (the rest is used for making pellets for heating or other technical and/or food purposes). The total production of biodiesel in 2014 was about 220,000 tonnes. The production of ethanol from biomass was about 130 dam^3. About half of the ethanol production is based on processing of sugar beet and the second half is based on cereals. Short rotation coppices – another sector in the field of renewable energy production – currently occupies about 1600 ha of agricultural land. The number of agricultural AD plants increased from 8 in 2004 to almost 400 in 2014. About 4000 ha of farmland were withdrawn from the agricultural land fund for the construction of photovoltaic panels in between 2009 and 2012 according to the Czech Agrarian Chamber [6]. So far, there is no wind energy project owned by farmers implemented in the country.

4. Research methodology

4.1. Case study area

Our case study covers two districts (LAU1) of the Hradec Králové Region, which is located in the northern part of the Czech Republic, on the border with Poland (see Fig. 1). The studied districts differ significantly depending on the climate and geographic conditions and they well represent two dominant types of agricultural production areas in the country. The Hradec Králové District (hereinafter HK) belongs to the rape production area (which occupies about 35% of the country's total area), while the Trutnov District (hereinafter TU) half belongs to the potatoes production area (52%) and half to mountainous production area (8%). HK is thanks to its natural conditions (the river Elbe lowland) one of the most important agricultural areas in the country. Agricultural land covers about 70% of the district, including 84% of arable land and 11% of permanent grassland. TU is characterized by less favourable mountainous conditions (higher altitudes, poorer soils, lower temperatures, high rainfall totals), which limit the options of agricultural production. Agricultural land covers only 44% of the district area, of which more than half is arable land and 40% is permanent grassland. About 80% of the district area is classified as a less-favoured area for agricultural production. Selected data about the land use and structure of agricultural holdings in the districts are in Table 2.

4.2. Survey design and methodological limitations

Our study draws upon a questionnaire survey carried out via e-mail during November and December 2014. Contact information for agricultural holdings were provided by the State Agricultural Intervention Fund. All together more than 500 agricultural holdings are registered in the studied districts. The aim was to include in survey roughly equal representation of holdings in terms of location (district) and type of farm (legal form, size, production focus). We have contacted all farming enterprises (legal entities) doing business in the districts and more than half of individual (self-employed) farmers. All together 75 completely filled questionnaires useful for analysis were gathered. The sample included 34 out of 78 enterprises (44% representation) and 41 out of 429 individual farmers (10% representation). The subjects in sample manage farmland of total area of nearly 60,000 ha, which are two thirds of all agricultural land in the districts. The structure of sample according to the legal form of holdings is in Table 2. A more detailed characteristics of the sample are presented in Appendix A.

Some distortion of results (particularly as concerns the overall level of involvement in energy activities) may be present as a consequence of a lower share of natural persons and higher share of respondents with tertiary education (managers of companies) in the sample. The problem of people with less interest in a study and with only basic education being less likely to respond to questionnaires than people with higher education and greater interest is a general phenomenon observed when distributing questionnaires by post [46]. With this in mind we have to assume that the

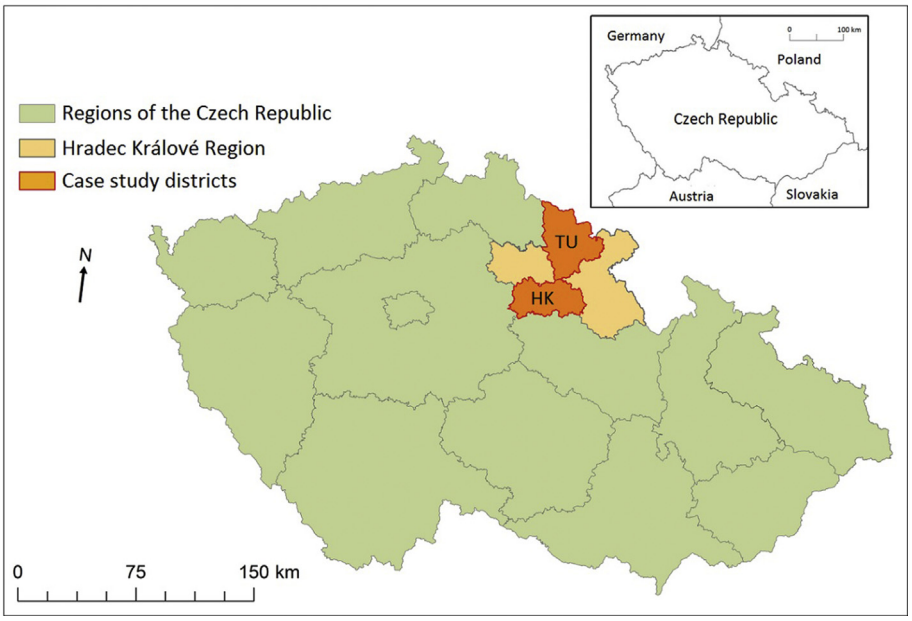

Fig. 1. Map of the Czech Republic with case study areas.

observed overall rate of involvement in energy activities is probably higher compared to reality, since individual self-employed farmers with lower education (which are under-represented in our sample) proved to be less likely involved in RE enterprises. A possible deviation relates in particular to growing energy crops and biomass because certain types of energy business (e.g., operation of AD plants or large PVs) are allowed only to legal entities which are well represented in our sample. Nevertheless, our study was not aimed primarily at absolute numbers but rather at exploring specific relative numbers and relationships (differences in the level of adoption of specific activities according to types of farms and between the districts).

Many farmers (in particular representatives of small family farms with negative attitudes to agro-energy business) described their views on the issue quite extensively in the contents of their emails, without ever filled out a questionnaire. These views were not included in statistical analysis. Their comments were, however, very useful for our research, because they contained a number of specific comments and practical experiences. This qualitative information was included in the Results section on factors affecting adoption or non-adoption of RE enterprises (Section 5.4).

Table 2
Selected land use data and number of agricultural holdings in the districts.

Land use	HK	TU
Arable land (ha)	50,771	15,594
Permanent grassland (ha)	3964	20,356
Maize for grain (ha)	3024	8
Silage maize (ha)	3144	1453
Rape (ha)	6673	2123
Number of pigs	47,463	7421
Number of cattle	15,662	17,997
Agricultural AD plants (number/installed capacity in MW)	6/7.2	7/3.4
Agricultural holdings by legal form (total/in survey sample)		
Farm cooperative	7/4	4/2
Joint stock company	14/6	11/4
Limited liability company	20/13	22/5
Agricultural entrepreneur - natural person	222/21	207/20
Total	263/44	244/31

Source: Czech Statistical Office [45], and authors' survey

5. Results

5.1. Farmers' attitudes to the productive role of agriculture and agro-energy business

Our survey revealed significant variance in farmers' attitudes to the main mission of agriculture and to the involvement of farmers in non-food-productive activities. At the same time, a considerable discrepancy between personal attitudes of farmers and actual practice of their firms was detected. This discrepancy could be characterized by saying *it's not right, but we* (*our firm*) *do it … since it brings money* (a literal statement of an interviewed farmer). More than half (60%) of respondents agreed with a traditional view' that farmers should deal only with food and livestock production (see Table 3). On the other hand, almost half of Czech farmers consider agro-energy a way of business, which economically diversifies and stabilizes farms. And almost half agreed that in the future energy production will be even more important component of farm business.

The traditional view among Czech farmers is more likely held by females (67%) than males (56%), by people with basic education (100%) and secondary education (68%) than people with higher education (50%), and more likely by private farmers (67%) than managers of larger companies and cooperatives (35%). Agro-energy business is most likely accepted by the younger generation of farmers (only one third of respondents under 30 years of age keep the traditional view).

Our survey detected a significant discrepancy between farmers' personal attitudes and actual activities of their firms and enterprises. Almost three fourths (72%) of proponents of the traditional view (that farmers should produce only food and animal feed) run some activity related to energy production → most often growing biofuel crops or biomass for combustion. The percentage of subjects, which already adopted some energy enterprises, is paradoxically higher among proponents of the traditional view than among farmers with more liberal standpoints (75% compared to 66%). A greater representation of the traditional view on agriculture is among the farmers growing energy crops (65%) and biomass (55%) than among the owners of AD plants (45%) and solar plants (30%). It

Table 3
Distribution of farmers' responses to presented statements.

Statement/Response (%)	Strongly disagree	Disagree	Neither	Agree	Strongly agree
Farmers should produce only food and animal feed	9	23	8	23	37
Agro-energy is a way of business that economically diversifies and stabilizes farms	4	14	23	38	10
In the future energy production will be even more important component of farm business than today	8	26	20	35	12

Source: authors' survey

shows that growing energy crops and biomass is considered a natural part of farming more often than producing electricity in AD or solar plants.

5.2. Factors affecting the rate and type of involvement in RE enterprises

Significantly higher percentage of farms engaged in energy activities was found in HK District (Table 4). Likewise, there is a higher relative frequency of farms running more than one activity. HK District has a significantly larger proportion of farms, which focused on cultivation of crops for the production of biodiesel or ethanol, while in TU District the production of biomass for combustion is more obvious. We have not found, however, statistically significant differences in the extent of developing AD plants and solar power plants.

The extent of adoption of energy activities is influenced both by climatic and physical-geographical conditions and the type of farm (Table 5). The adoption of energy activities is positively correlated with company size and area of cultivated land, and negatively correlated with the degree of focus on livestock production. Growing crops for biodiesel and ethanol production is typical for large and medium-sized companies (cooperatives, joint stock companies) that have larger areas of land (more than 100 ha). On the contrary, self-employed farmers and small enterprises, which have less land area, are more likely to produce biomass for combustion and use own grounds and roofs for implementing solar systems.

Table 6 shows correlations between specific activities and characteristics of farms. The strongest correlation is between the company size and cultivated land area and growing biofuel crops. A strong correlation is also between the operating own AD plant and the production of animal waste that correlates with the area of land. On the contrary, the area of land is negatively correlated with the production of biomass for combustion (usually short rotation coppices).

Table 5
Correlations of subject characteristics and the adoption of at least one of the activities.

Independent variables	Correlation value
Area of cultivated land	0.555**
Legal form of the subject	0.444**
Company size (number of employees)	0.383**
Production focus (% share of livestock production)	−0.377**
Location in a district (HK = 1, TU = 2)	−0.298*

Note: The values of correlation (Pearson's r) are significant at the level ** <0.01 or * <0.05.

5.3. Most common combinations of RE enterprises

Based on the analysis of inter-correlations between the activities we have identified four most common types of combinations of on-farm RE energy enterprises. These types are characterized as follows:

Type 1: Growing crops for biodiesel and ethanol production.

This type represents the most common combination of activities. Typical examples of this type are large or medium-sized companies (cooperatives or joint-stock companies) with more than 100 employees, which have large areas of leased land (at least

Table 4
Geographical and inter-firm differences in energy-activities.

Activity/Relative frequencies (%)	District		Type of company				Total
	HK	TU	NP	LIC	JSC	CO	
Growing crops for biodiesel production	75	29	37	64	88	100	58
Growing crops for ethanol production	43	11	21	18	41	83	30
Growing biomass for combustion	7	25	16	17	9	0	15
Operating own solar power plant	14	11	13	9	18	0	12
Operating own AD plant	9	7	2	18	6	50	9
Supplying animal waste for biogas plant	7	7	0	9	12	33	7
Operating own wind power plant	0	0	0	0	0	0	0
Total							
At least one of the activities	**86**	**50**	**58**	**73**	**94**	**100**	**73**
Two different activities	43	11	21	36	47	67	32
More than two activities	9	14	5	9	18	33	11

Notes: HK = Hradec Kralove, TU = Trutnov, NP = Natural person, LIC = Limited liability company, JSC = Joint stock company, CO – Agricultural cooperative. Source: authors' survey.

Table 6
Inter-correlation matrix of specific energy-activities and characteristics of subjects.

	Ethanol crops	Biodiesel crops	Biomass	AD plant	Animal waste	Solar power
Ethanol crops	1.000					
Biodiesel crops	**0.432****	1.000				
Biomass for combustion	−0.189	−0.184	1.000			
AD plant	0.194	**0.274***	−0.135	1.000		
Animal waste	0.178	**0.229***	0.039	**0.649****	1.000	
Solar power plants	−0.152	−0.103	**0.203***	−0.120	−0.100	1.000
District	**−0.352****	**−0.330****	**0.295***	0.082	−0.016	−0.067
Company size	**0.406****	**0.519****	−0.040	0.202	0.168	0.014
Land area	**0.466****	**0.783****	**−0.273***	**0.316****	**0.263***	−0.156
Focus on livestock production	0.036	**−0.329****	−0.074	0.025	0.100	−0.201

Notes: The values of correlation (Pearson's r) are significant at the level ** <0.01 or * <0.05 Significant correlations are in bold. Source: authors' survey.

over 100 ha but often more than 500 ha). They focus on the plant production or mixed production with a predominance of crop production. More companies of this kind are located in HK district.

Type 2: Growing crops for biodiesel and operation of own AD plant (with crops as primary source).

This is the second most frequent combination of activities. This type is represented by larger medium-sized companies (according to number of employees), which have large land areas (over 500 ha), and focus on mixed production with a predominance of crop productions. Energy crops (seed maize, silage maize, grass silage) are utilized as a primary source for AD plants. More companies of this kind are located in HK district.

Type 3: Growing crops for biodiesel, production of animal waste (manure) and operation of own AD plant (with manure as primary source).

This type is represented by small or medium-sized holdings (limited liability companies or small cooperatives) with 10–100 employees, which have, however, of large land areas (over 500 ha). They focus on a mixed production, including energy crops growing as well as pig and cattle breeding. They produce own animal waste (manure), which is used as primary source for own AD plant. They are located in the same way in both studied districts.

Type 4: Production of biomass for combustion and operation of own solar plant.

Combining the production of biomass for combustion (including short rotation coppices) and operation of own ground-mounted or roof-mounted solar systems is typical for smaller firms and self-employed agricultural entrepreneurs, which specialize on plant production or mixed production with a predominance of plant production. The area of land utilized by these holdings is below 10 ha. They are more likely located in TU District.

5.4. Motivation factors and barriers affecting the adoption of RE enterprises

The main reason for adopting some RE enterprise as reported by farmers is economic diversification and stabilization of farm (Table 7). This reason is linked to the legislative support and subsidies (rated as the third most important factor). A landscape stewardship has been rated as the second most important factor, including both aesthetic reasons (shaping the cultural landscape) and practical reasons (suitability of the crop rotation for specific areas/soils).

The degree of importance of the landscape stewardship factor positively correlates particularly with the cultivation of crops for biodiesel production. The factor of sustaining jobs was rated as more important by large companies with more employees and larger land areas. The reason to utilize otherwise unused land was rated as the less important factor. This factor significantly correlates with the implementation of solar power systems. Frequent changes in the legislation, which is, moreover, perceived as complicated and unclear have been reported the main barriers of the adoption of RE enterprises. The legislative changes (e.g., changes of feed-in tariffs, retroactive actions, etc.) are linked to economic uncertainties and unprofitability.

Many farmers (in particular representatives of small family farms with a negative attitude towards agro-energy business) described their views on the issue quite extensively in the contents of their emails, without ever filled out a questionnaire. The most commonly criticized form of business was the operation of AD plants and growing crops primarily for the use in these facilities, and construction of solar panels on quality agricultural land. Farmers stressed negative impacts related to these forms of business, including the occupation of large areas of farmland, the creation of monocultures, and increasing soil erosion. State subsidies for the construction of on-farm AD plants and solar power plants were widely criticized. Most of these opponents stressed out that farmers should concentrate solely on the production of crops and livestock for food purposes.

6. Discussion

Results of this study provide new insights about the development of on-farm renewable energy enterprises in Europe. The proportion of supporters of the traditional view (that farmers should only produce food and animal feed) among Czech farmers detected by our survey remains about the same as in other smaller post-communist countries (e.g., Slovakia or Lithuania) but higher than it was reported from Western countries, such as Germany, UK or Sweden [15,19,9,3]. However, the majority of Czech farmers takes a pragmatic approach and they run some RE production activities for economic reasons to diversify and stabilize their farm business. Confirmation of economic motivation as the main reason for agro-energy business is in line with findings of most recent studies from the UK [24,25,30].

The observed discrepancy between farmers' individual attitudes and utilitarian practice of their farms ("*… it is not right to use arable land for energy production … but we do it since it brings money to keep our farming business running*") well characterizes the attitude of the entire Czech population. While people in countries such as Austria or Germany more likely support the renewable energy development of the conviction that it is a right energy policy (to replace dirty fossil fuels and dangerous nuclear energy), in the Czech Republic people accept renewable energy projects mostly for economic reasons but they doubt about the correctness of this way [32,47].

The observed level of the involvement of Czech farms in agro-energy business (meaning the adoption of at least one activity related to renewable energy production) is very high in our sample - reaching 90% among larger companies, 60% among small farms,

Table 7
Motivation factors and perceived barriers to run agro-energy activities.

Motivation	Mean score	Barrier	Mean score
Economic diversification/stabilization	4.12	Frequent changes in legislation	3.84
Landscape stewardship	3.30	Complicated and unclear legislation	3.64
Legislative support and subsidies	3.16	Economic unprofitability	3.47
Sustaining jobs (employment)	2.88	Lack of information	2.78
Improving company image	2.78	Fear of failure in new business	2.64
Use of otherwise unused land	2.70	Disruption of company image	2.36

Source: authors' survey.

and 70% in total. We have to assume, however, that the overall rate of involvement in these activities at the country level will be lower because small family farms and self-employed farmers, which proved to be less likely involved in energy business were significantly under-represented in our sample. High rates of adoption of RE activities relates in particular to the cultivation of biofuel crops and biomass for combustion. The level of implementation of energy facilities directly producing electricity (AD plants and solar power plants) is much lower (only about 15%). This level detected in the sample seems to be very close to reality at the country level. According to data from the last agro-census (2010), there about 3000 agricultural enterprises (legal persons) were registered in the Czech Republic, while there are about 400 operated agricultural AD plants. As far as state subsidies for AD plants are intended only to legal persons it means that about one in ten company operates own AD plant. The percentage of farms operating own solar power plants is probably even higher having regard to the enormous increase in the installed capacity of PVs during the last five years and the amount of agricultural land earmarked for their implementation [34]. Unfortunately, there are no exact data about the ownership patterns of implemented on-grid solar systems at the country level.

In general, the adoption of agro-energy activities is positively correlated with company size and area of cultivated land, and negatively correlated with the degree of focus on livestock production. These results are broadly similar to earlier studies on the uptake of renewable energy production and associated enterprises from the UK and USA [18,24,25,30,48]. In terms of specific activities adopted by Czech farmers, growing crops for biodiesel and ethanol production (in the highest degree rape, maize and sugar beet) is typical for large and medium-sized companies that have larger areas of land. On the contrary, self-employed farmers and small agricultural holdings, which have less land areas are more likely to produce biomass for combustion (e.g., sorrels, short rotation coppices) and use own grounds and roofs for implementing solar systems.

Our study contributes to the current knowledge by providing empirical evidence on how the adoption of specific activities is influenced by both the type of farm and location factors. While there are significant differences between the studied districts with different climatic and geographic conditions in the type and extent of energy crops and biomass cultivation, the expansion of AD plants and solar power systems was observed the same in both areas. This finding raises the hypothesis that subsidies (feed-in tariffs) for solar energy are so high that they may outweigh unsuitable climatic conditions (it is profitable even in districts with low solar irradiation and low production). The similar situation is with the AD plants where there are also different options as regards the feedstock for the production of biogas (silage, manure, etc.). On the other hand, the subsidies for growing energy crops suitable for the production of ethanol or biodiesel are not so high to outweigh unsuitable climatic conditions (in other words, it's not good deal to grow corn in foothill landscapes but it can be profitable to grow the fodder sorrel).

Such findings raise some questions for future research, in particular whether the identified spatial patterns in the diffusion of specific renewable energy production enterprises are typical only for the Czech Republic or are they valid for other European countries, specifically those which have experienced communist histories and similar transformation trajectories? Resolving such issue, however, would require comprehensive and reliable statistical data, which will be provided only in cooperation with responsible state institutions and farmers, and hopefully will be open-sourced for further research.

Our findings regarding the regional levels of adoption of specific energy activities support the results of studies analysing the 'helter-skelter' diffusion of AD plants and large solar power plants at the country level [34,4]. Czech agricultural sector seems to be strongly affected by both agricultural and energy policy applied. Several misleading settings of supportive schemes have caused discrepancies between officially planned aims of support and their actual unintended regional and local consequences. For example, the subsidies for the construction and operation of agricultural AD plants have caused an increase in the area of purpose-grown plants like maize and a limited use of communal organic waste. The extremely high feed-in-tariffs for electricity produced by ground-mounted solar power plants have caused a coverage of large quantities of arable land by photovoltaic panels in rural areas at the expense of smaller rooftop-mounted systems or projects on post-industrial brownfields in urbanized areas [49,50]. Renewable energy policy settings in the Czech Republic have been significantly affected by lobbyist groups [36], which have so far tended to deform mentioned policies rather into sources of income for large companies and speculative investors than would be contributions to the environmental improvement and sustainable socioeconomic stabilization of rural areas [4,51].

7. Conclusions

Our comparative case study has fulfilled its objectives – to explore the current attitude of Czech farmers towards transformation of the agricultural sector and development of agro-energy business, to check the level of farmers' involvement in renewable energy production enterprises, to identify main types and combinations of adopted energy producing activities, and classify factors affecting the adoption of specific activities. Most Czech farmers hold the traditional view about the privileged food-producing role of agriculture, while they actually perform some activities related to renewable energy production for economic reasons. This discrepancy between attitudes and behaviour toward renewable energies seems to be characteristic for the entire Czech population.

While we observed significant differences in the types and extent energy crops and biomass cultivation in the studied districts with different climatic and geographic conditions, the expansion of AD plants and solar power plants seems to be same in both studied districts. The adoption of energy activities by Czech farms is positively correlated with the company size and area of cultivated land, and negatively correlated with the degree of focus on livestock

production. While growing biofuel crops and operating AD plants are typical for large and medium-sized enterprises with a large area of cultivated land, individual farmers and small enterprises with less land area are more likely to produce biomass for combustion and use own grounds and roofs for implementing small-scale solar systems.

The relatively high level of involvement of Czech farmers in agro-energy business is likely to be influenced by relatively high (in the context of EU) subsidies and tax exemptions for biofuels and high feed-in-tariffs for the electricity produced from biogas and solar energy, while relatively low subsidies in the agriculture in general (the subsidies in the Czech agriculture in 2015 just reached about 80% of the average of old EU countries) and therefore the low competitiveness of Czech products. In this respect, the agro-energy business for Czech farmers – particularly for large and medium-sized enterprises – represents a very important source of income to stabilize their business. It seems to be very important to diversify more the subsidies for renewable energy and hamper the expansion of specific technologies and practices in respect to geographical conditions and the need for the landscape management and protection of farmland. It is also important to increase a general public awareness of the environmental and economic costs and benefits of the development of renewable energy sources as alternatives to traditional fuels, so they will be supported not only for economic reasons.

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Appendix A

Structure of the survey sample

Characteristic of subject		Share [%]
Legal form of subject	Agricultural entrepreneur (natural person)	51
	Limited liability company	15
	Joint-stock company	23
	Cooperative	11
Size (number of employees)	small (less than 10 employees)	64
	medium (10–50 employees)	20
	large (50–250 employees)	16
	extra-large (more than 250 employees)	0
Utilized land area (ha)	<10 ha	18
	10–50 ha	15
	50–99 ha	12
	100–500 ha	14
	>500 ha	42
Average land area per farm (ha)	Agricultural entrepreneur	135 ha
	Limited liability company	570 ha
	Joint–stock company	2190 ha
	Cooperative	2553 ha
Production focus	100% of livestock production	5
	mixed with predominance of livestock	31
	mixed with predominance of plant	32
Education of respondent	Primary	10
	Secondary	35
	Tertiary	55
Age of respondent	less than 30 years	4
	30–39 years	15
	40–49 years	34
	50–59 years	28
	60 and more years	19
Gender of respondent	Male	88
	Female	12

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