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PRODUCTION ANALYSIS OF BIOGAS PLANT IN THE CZECH REPUBLIC

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Abstract

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The paper deals with an agriculture production analysis of biogas plant in the Czech Republic and evaluates the effect of input-factors and their relevance. Cobb-Douglas functions for crop, livestock and total agriculture production are used. Econometric models are used for structure and magnitude determination of land and labour factors at individual farms, which lead to an increase of production defined in scenarios. Estimations are based on cross-section data. Results indicate statistical significance and the economically highest effect of land and fixed assets on the total agriculture production. The results of first period model show, that there is preferably a need for an increase of fixed assets when enlarging the livestock production. There is an increase of the importance of wages in total and livestock production in 2011 compared to 2010. The crop production is dependent on land are in the most, but the model must be rejected because of parameters intensity and economic justification. Quantification of relationships among variables can be used for planning of the whole production or its components.

Keywords: agriculture production, farm, livestock production, crop production, Cobb-Douglas function

INTRODUCTION

Biogas production is important and topical theme in agriculture, not only in terms of bioenergy production, but also in terms of industrial processing. In recent years, most European countries have tried to establish a biogas plant as an economically viable power industry. Energy production from renewable sources is becoming increasingly important issue in the world, partly because of the possibility of depletion of fossil fuels, but also due to the protection of the environment (Tatlidil *et al.*, 2012). The process of biogas production has undergone and is still undergoing extensive research which focuses on biogas (Banks *et al.*, 2011; Prade *et al.*, 2012), improvement of biogas production (Ward *et al.*, 2008) or configuration of other production processes (Poeschl *et al.*, 2012).

In general it can be concluded that biogas production is recognized as an environmentally friendly use of biodegradable waste. However, some authors (e. g. Kimming *et al.*, 2011) believe that energy from biomass is a suitable solution for keeping environment because it is more environmental friendly in terms of greenhouse gas emissions. On the other hand, a negative consequence of these resources is the non-food use of agricultural land.

Recently, biogas plants have experienced dynamic growth not only in Europe but also in other continents (Asia, America, and Africa). Biogas represents 1.3% of the annual production of electricity and contributes by more than 10% to renewable energy sources. Outlooks of this method of energy production forecasts annual growth rate of 7% up to total installed capacity of 22,000 MW in 2025 (Maghanaki *et al.*, 2013).

Murphy and Power (2009) considers the available agricultural land as key limiting factor of the biogas production. The available agricultural land can be utilized for cultivation of the input substrate. The Czech Republic has an advantage of relatively large sized farms which are able to provide sufficient agricultural area for energy purposes. On the contrary, in other EU countries like Poland or Croatia there are relatively small farms with limited ability to integrate biogas plant (Puksec, 2011). Authors as Jenkins (1997) and Walla and Schneeberger (2008) also try to set optimum operating plant size of biogas plant with respect to the investment support and tariff for green electricity. They conclude that only plants with a size of 100 or 250 kW_{el} can cover their costs through sales of electricity. Larger plants would need lower production costs than those resulting in the calculations if they were to turn a profit at the relevant electricity price.

The paper uses Cobb-Douglas production function to process production analysis of agricultural biogas plants. At the beginning of the 20th century, the Cobb-Douglas production function was perceived as historic landmark in economics. Production function generally quantifies the relationship between the inputs and outputs of the production process. It may contain one or more inputs or outputs. The inputs can be assumed either as fixed or as variable (work, land, assets, or change in technology). It is also possible to analyze the production flexibility, which is defined as the percentage change in the output caused by the percentage change in input (Debertin, 1986).

With the development of industrial activities, a large number of economic analyzes were transformed to enable application in individual companies or branches. Such models are currently highly desirable (Walsch, 2003). In the Czech Republic, Mach and Čechura *et al.* (2010) deal with the Cobb-Douglas production function for modelling of cattle breeding production. Cobb-Douglas production function also enables to model energy issues with regard to technological progress. For example, the results of empirical research show that technological progress reduces the energy intensity of Chinese industry by 6.3% year after year (Yuan *et al.*, 2009).

The analysis of biogas plant can be drawn in several steps. The first step is to analyze traditional production field as total, crop and livestock production. The second step can be focused on biogas production and its related input factors and their structure. It is convenient to pay attention to a cost function as well to gain more complete information about relationships and measure the technical efficiency of this type of farms. The focus on this paper is on the traditional production output. The aim of the paper is to analyse agriculture production of biogas agriculture companies in the Czech Republic and evaluate the effect of input-factors and their relevance. Moreover, models are used of structure and magnitude determination of land and labour for individual farms, which lead to an increase of production defined in scenarios.

METHODOLOGY

The data set obtains information from 14 agricultural companies in 2010 and 2011. The analysis focuses on the agriculture companies, which have started to operate biogas plants since 2010. The individual data from energy audits, balance sheets and income statements are used as variables in the analysis. A representative sample originally contained 34 companies, but due to the unavailability of some essential financial data it was necessary to reduce the sample to 14 companies. Data from 2012 have not been available for all companies. So, the analysis is based on historical data 2010–2011. The variables are described below.

Econometric models are used for purposes of the paper. Cobb-Douglas production function is chosen for analysis of total agricultural production, crop production and livestock production. Relevant factors used in the regression for evaluation of production changes are a labour, approximated by wages of employees, capital, approximated by fixed assets of a company, and a land as important production factor in agriculture.

Declaration of Variables

CP ....total annual crop production in million CZK.
LP ....total annual livestock production in million CZK.
TAP ....total annual agriculture production in million CZK.
LD.......available arable land of agricultural companies in ha.
WG.....total annual wages of employees in million CZK (proxy for labour input).
FA.......fixed assets in million CZK.

Estimated Cobb-Douglas functions are follows:

$$TAP_i = \alpha_0 LD_i^{\alpha_1} WG_i^{\alpha_2} FA_i^{\alpha_3} \varepsilon_{1i}, \qquad (1)$$

$$CP_i = \beta_0 LD_i^{\beta_1} WG_i^{\beta_2} FA_i^{\beta_3} \varepsilon_{2i}, \qquad (2)$$

$$LP_i = \gamma_0 WG_i^{\gamma_1} FA_i^{\gamma_2} \varepsilon_{3i}. \qquad (3)$$

A crop production and a total agriculture production are dependent on a land, a labour and an assets. Livestock production is influenced by labour and assets only, because the land does not directly affect changes in livestock production.

Functions mentioned above after logarithmic transformation are estimated according to Single-year Cross-section Model by OLS method. The estimation for each year separately is based on an assumption of changing parameters during the time. The land of farms is stable during years, but contrary there are differences in wages of employees and value of fixed assets during selected years and in final production naturally. Therefore the structure of inputs is changed and it can have a different effect to the production. Each model is tested under the Gauss-Markov assumptions. White test and Breusch-Pagan test are used for testing heteroskedasticity. Normality of stochastic variable is tested by Jarque-Bera test. Collinearity between explanatory variables is checked by Variance Inflation Factors. Estimated parameters, i.e. elasticity from the last investigated year, are used for simulations of scenarios. Simulations are connected with the question by how many particular agricultural producers have to increase a particular input, if they want increase their total production by 1% and other inputs remain the same. The first scenario is connected with the change of land, the second scenario is related with the change of fixed assets and the last scenario calculates the change in wages of employees. The software GRETL, ver. 1.9.1 was used for estimation and testing purposes.

RESULTS

The first estimated model is connected with a total agricultural production (TAP). Results are shown in the Tab. I. The OLS1 declares estimation of the model in 2010 and the OLS2 contains model output in 2011. A notation l_ used in estimation output denotes natural logarithm of particular variables.

The variation of total agricultural production is explained by 93.84% in the year 2010 and by 91.98% in the year 2011 by selected explanatory variables. Models for both years are statistically significant at 1% level of significance according to the F-test. The autocorrelation, heteroscedasticity and collinearity are not present. All p-values suggest no rejections of null hypotheses in any traditional levels of significance and collinerity statistics did not exceed a level, where collinearity problem could appear.

In connection with the analysis of production in 2010, parameters of land and fixed assets are statistically significant at 5% resp. 1% level of significance. Fixed assets have the greatest effect on the overall production. If the amount of fixed assets increases by 1%, total agricultural production will increase by 0.49%. Land area also has a significant effect on production. Its growth by 1% leads to an increase of production by 0.45%. In contrast, variable "wages" which represents the labour input shows the smallest effect in 2010 and the parameter is not statistically significant. All effects of variables are inelastic which corresponds with the sector assumptions. The results reveal decreasing returns to scale but the value is very close to constant returns to scale

$$\sum_{i=1}^{3} \gamma_i = 0.9866 .$$

Estimates for the year 2011 also show statistically significant effects of land and fixed assets on production. The increase of fixed assets by 1% causes an increase of output by 0.30%. The parameter "fixed assets" is statistically significant at the 10% level of significance. Growth of the land area by 1% causes an increase in output by 0.33%. The parameter is significant at the 5% level of significance. The intensity of the individual parameters is slightly lower compared to the previous year. On the contrary, an increase in intensity of variable "total wages" is obvious compared to 2010. An increase of wages by 1% leads to an increase in the total production by 0.38%.

I: *Estimation of the model (1), total agricultural production, OLS1 in 2010, OLS2 in 2011*
Dependent variable: l_TAP

Coefficient estimation			Statistical characteristics			Econometric verification		
Estimate:	**OLS1**	**OLS2**	**Estimate:**	**OLS1**	**OLS2**	**Estimate:**	**OLS1**	**OLS2**
const	−1.8113	−0.8443	Num. obs.	14	14	Breusch-Pagan test:		
	(−1.8108)	(−0.9641)	R-squared	0.9384	0.9198	LM stat.	0.4651	0.2662
	[0.1003]	[0.3577]	Adj. R-sq.	0.9199	0.8957	P-value	[0.9265]	[0.9663]
l_LD	0.4520**	0.3312**	F(3.10)	50.764	38.208	White test:		
	(3.0056)	(2.3127)	P-value (F)	[0.0000]	[0.0000]	LM stat.	4.9337	4.9376
	[0.0132]	[0.0579]	AIC	−11.389	−6.315	P-value	[0.8400]	[0.8397]
l_WG	0.0426	0.3842*	SIC	−8.833	−3.759	Jarque-Bera test:		
	(0.1984)	(−0.1794)	H-Q	−11.6256	−6.552	Chi-square	4.2588	1.8349
	[0.8467]	[0.0579]				P-value	[0.1189]	[0.3995]
l_FA	0.4920***	0.30220*				Collinearity (VIF)1)		
	(3.3988)	(2.1745)				l_LD	4.491	2.848
	[0.0068]	[0.0548]				l_WG	9.129	4.255
						l_FA	3.84	2.489

Note: T-stat ( ), p-value [ ] *** p < 0.01; ** p < 0.05; * p < 0.1

Note: 1) if values > 10 may indicate a collinearity problem

Source: own calculations, Gretl 1.9.1

Parameter of variable “wages” is also statistically significant at the 10% level of significance.

The growing influence of a variable “wages” together with a comparison of wages development and number of employees in the enterprises indicates an increase of workers’ qualification. The data file shows a decrease in the total number of workers from 1,140 to 1,103 (reduction from 81 to 79 workers on average). But there was a rapid increase in labour costs from 286.849 million CZK to 300.5 million CZK per year. It means that average wage costs increased from 204.9 million CZK to 214.7 million CZK per farm. Moreover, the increasing returns to scale result from the analysis in 2011. There has been very small increase in the coefficient in their summation, but the resulting sum,

$$\sum_{i=1}^{3} \gamma_i = 1.0176\,,$$

exceeds threshold of constant returns to scale. It can be concluded that labour is the driving force of returns to scale because there was also an increase in the strength and significance of labour as compared to the previous period. In contrast to 2010, the influence of various factors on the production is balanced in terms of their power. Results indicate more efficient use of inputs in 2011.

The second estimated model is connected with a crop production, which is dependent on the labour, fixed assets and land. The estimation output is shown in the following Tab. II.

The estimated models are statistically significant at 1% level of significance according to the F-test. The variability of crop production was captured by more than 80%. The only statistically significant parameter is parameter of variable “land area”. However, the parameter of land area is bigger than one and parameters of wages and fixed assets are negative. This is inconsistent with economic theory. Therefore, the model can’t be accepted as functional and must be rejected. It is probably needed to include other variables such as exact material inputs, information about land type, climatic condition in investigated areas and etc. to obtain a correct model.

The last model type describes a relationship between livestock production and inputs “fixed assets” and a “labour” (Tab. III). The land is not considered in this model because it does not have direct impact on livestock production.

The models of livestock production have the lowest goodness-of-fit, but the R-square still reaches quite high values, namely 74% or 64% respectively. The F-test confirms statistical significance of the model at 1% level of significance in both estimated years. There is no problem with non-normality or collinearity in both models. The null hypothesis of homoscedasticity can’t be rejected according to the White test. The second test, Breusch-Pagan indicates slight heteroscedasticity, but only at 10% level of significance. Because the threshold level of significance is set at 5%, therefore the model is determined as sufficient for future purposes.

The estimated parameter of fixed assets in the model from 2010 is the only statistically significant parameter in the model. In 2010, there is obviously a big effect of the fixed assets on the livestock production. An increase of fixed assets by 1% leads to an increase of livestock production by 0.88%. The change is non-elastic. In the case of labour, approximated by wages, an increase of wages leads to an enlargement of livestock production by 0.20%.

II: *Estimation of the model (2), crop production, OLS1 in 2010, OLS2 in 2011*
Dependent variable: l_CP

Coefficient estimation			Statistical characteristics			Econometric verification		
Estimate:	**OLS1**	**OLS2**	**Estimate:**	**OLS1**	**OLS2**	**Estimate:**	**OLS1**	**OLS2**
const	−5.748**	−4.8660**	Num. obs.	14	14	Breusch-Pagan test:		
	−2.4643	−3.0859	R-squared	0.8179	0.8482	LM stat.	2.8625	1.9536
	0.0334	0.0115	Adj. R-sq.	0.7633	0.8026	P-value	0.4133	0.5821
l_LD	1.3533***	1.17266***	F(3.10)	14.9703	18.622	White test:		
	3.8592	4.5466	P-value (F)	0.0005	0.0002	LM stat.	11.5813	10.5384
	0.0032	0.0011	AIC	12.318	10.154	P-value	0.2380	0.3087
l_WG	−0.2007	0.1045	SIC	14.874	12.7108	Jarque-Bera test:		
	−0.4009	0.3234	H-Q	12.081	9.9179	Chi-square	0.2389	1.2894
	0.6969	0.7531				P-value	0.8874	0.5248
l_FA	−0.1455	−0.1952				Collinearity (VIF)1)		
	−0.4311	−0.7804				l_LD	4.491	2.848
	0.6755	0.4532				l_WG	9.129	4.255
						l_FA	3.840	2.489

Note: T-stat ( ), p-value [ ] *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Note: 1) if values > 10 may indicate a collinearity problem

Source: own calculations, Gretl 1.9.1

III: *Estimation of model (3), livestock production, OLS1 in 2010, OLS2 in 2011*
Dependent variable: l_LP

Coefficient estimation			Statistical characteristics			Econometric verification		
Estimate:	**OLS1**	**OLS2**	**Estimate:**	**OLS1**	**OLS2**	**Estimate:**	**OLS1**	**OLS2**
	−1.3789	−0.7053	Num. obs.	14	14	Breusch-Pagan test:		
const	−1.2655	−0.542	R-squared	0.7443	0.6387	LM stat.	5.1758	5.3734
	0.2319	0.5987	Adj. R-sq.	0.6978	0.573	P-value	0.0752	0.0681
	0.2016	0.5586	F(2, 11)	16.0085	9.7225	White test:		
l_WG	0.6055	1.5028	P-value (F)	0.0006	0.0037	LM stat.	7.8862	7.5051
	0.5571	0.1610	AIC	14.0877	20.9268	P-value	0.1626	0.1857
	0.8812**	0.5516	SIC	16.0049	22.8439	Jarque-Bera test:		
l_FA	2.5469	1.4665	H-Q	13.9103	20.7493	Chi-square	2.2267	2.3831
	0.0272	0.1705				P-value	0.3285	0.3038
						Collinearity (VIF)1)		
						l_WG	3.391	3.391
						l_FA	3.391	3.391

Note: T-stat ( ), p-value [ ] *** p < 0.01; ** p < 0.05; * p < 0.1

Note: 1) if values > 10 may indicate a collinearity problem

Source: own calculations, Gretl 1.9.1

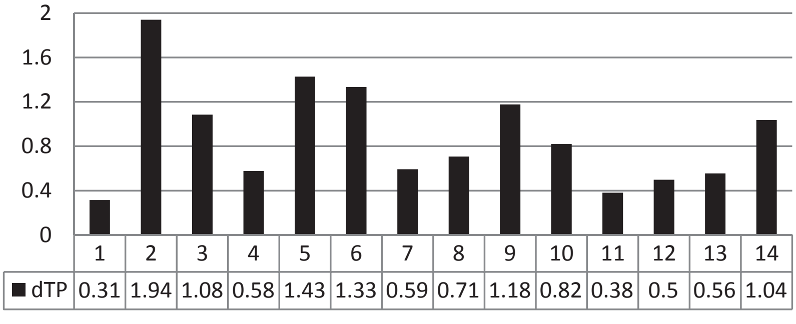
The next year 2011 is connected with the bigger effect of wages, as in case of total production. An increase of wages by 1% leads to an increase of livestock production by 0.56%. A similar effect is revealed for fixed assets as well. An increase of fixed assets by 1% would cause an increase of livestock production by 0.55%. All parameters are statistically insignificant, therefore it is not possible to generalize them as valid for population, but they are still valid for the sample.

The estimated parameters of total production model (1) are used for subsequent simulations. Each scenario (simulation) is related with final 1% increase of total production in comparison with the year 2011. The results of 1% positive change of total production for particular companies are shown in the Fig. 1. First simulation declare, by how much particular agriculture companies 1–14 should increase their land area to increase the total production by 1% in comparison with the year 2011 (ceteris paribus). The final change in land is shown in Fig. 2.

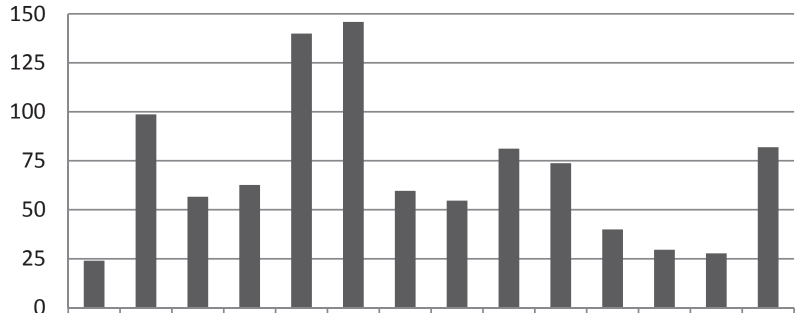
The second simulation is connected with the change of fixed assets, i.e. by how much should companies increase their fixed assets to increase the total production by 1% (ceteris paribus). The results are shown in Fig. 3. The last Fig. 4 shows a change in wages for one person per month which leads to a 1% increase of total production if other inputs remain at the same level as in the year 2011.

Results of the simulation show differences in land increase in individual companies. The increase ranges from 24 ha to 146 ha. The enterprises 2, 5 and 6 should make largest increase of land area. Simultaneously, these agricultural companies have the highest productivity in the sample. Thus, an increase of productivity by 1% has to be compensated by higher increase of land area. Likewise, the lowest increase of agricultural land would affect businesses 1, 12 and 13 who reported the lowest total production in 2011. These companies have the smallest utilized agricultural area.

Similarly, analogous conclusions can be formulated in case of fixed assets. Businesses 2,

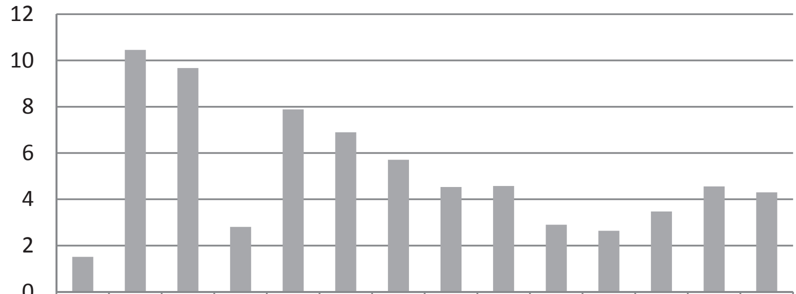


1: *Absolute equivalent of 1% change of total production in individual enterprises (million CZK)*
Source: own calculations



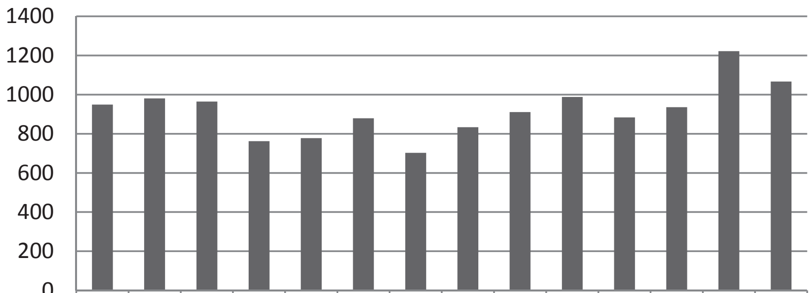
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
dLD	24	98.7	56.6	62.7	140	146	59.7	54.7	81.2	73.8	40	29.6	27.8	81.9

2: *An increase in the land in ha of particular companies to increase the total production by 1%*
Source: own calculations



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
dFA	1.51	10.5	9.67	2.81	7.89	6.9	5.71	4.53	4.57	2.9	2.64	3.48	4.56	4.3

3: *An increase in the fixed assets in million CZK of particular companies to increase the total production by 1%*
Source: own calculations



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
dWG	949	981	964	762	778	879	703	834	911	988	884	936	1222	1067

4: *An increase in the monthly wage of employees in CZK per month of particular companies to increase the total production by 1%*
Source: own calculations

5 and 6 should increase fixed assets by the range from 7 to 10.5 million CZK. It is considerably high amount.

In contrast, an increase of wages is very equal, approximately by one thousand CZK per month. There aren't any obvious differences among enterprises in terms of total production. Therefore, it is more advantageous for large enterprises (2, 5 and 6) to apply a change in the labour factor because the change in output is then compensated by relatively minor changes in the input compared to other companies and other input factors. In contrast, it is not advantageous for enterprise 13 to apply a change in the labour factor because such change would be then compensated by highest increase in labour costs.

CONCLUSION

This article analyzes the overall, crop and livestock production based on the Cobb-Douglas function. Within estimated models, crop production model had to be rejected because of its inconsistency with economic theory. Models of total and livestock production have undergone economic, statistical and econometric verification.

Estimates for 2010 emphasize a significant influence of land and fixed assets on total production. In the livestock production, fixed assets exhibit the greatest effect on the production. Compared to 2010, there is an increase of the importance of wages in total and livestock production in 2011. Based on the development of wages, number of employees and the growing influence of a variable "wages" in the model, a staff qualification seem to increase in 2011. After the growth of wages, individual factors/inputs have balanced impact on production changes. Elasticity of labour, land and fixed assets in relation to the total production ranges from 30–38%. In the case of modelling livestock production, elasticity of labour and fixed assets reaches a level of 55%.

Results reveal more efficient utilization of input factors in 2011 since the influence of individual factors is balanced. The changes of one factor run under certain risk diversification, i. e. the output depends not only on land or the fixed assets. Simultaneously, companies exhibit increasing returns to scale in a given year.

The simulation settings give the opportunity to use proposed models for planning changes in the input factors to increase production. An increase of production, as a consequence of an increase of land or fixed assets, corresponds to size of the company. Nevertheless, the sensitivity of wage increase against an increase of production is very similar among the individual companies regardless of their size and current level of their production. An increase of total production by 1% requires an increase of labour costs per employee approximately by one thousand crowns per month. However, simulation assumptions should also anticipate the existence of other factors such as climatic conditions, changes in the market environment, etc., that affect production and which should be included as fixed variables against baseline simulation.

The analysis carried out in this article is the initial step in research on companies with biogas plants. The next step in research is the extension of additional years of data and estimation of production functions through panel data. In addition to the production site, the future research will focus on cost function and determination of the technical efficiency through stochastic frontier functions. Finally, an analysis of biogas production, costs and their determinants is essential for complex view on production analysis of biogas plants.

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