The Influence of Investment Costs on Biogas Station Development and Their Impact on Greenhouse Gas Emissions from Czech Agriculture

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Abstract

The paper present the results for the influence of investment costs into biogas station on the amount of emissions from the agricultural sector. For the evaluation is applied structural analysis of major factors affecting the level of CO_2 emissions from agriculture. Among these factors are: the number of animals (converted to livestock units), cost of investment in biogas plants, the quantity of nitrogen fertilizers and the total amount of CO_2 emissions from agriculture. The results show that the investment costs haven´t significant influence despite the correct direction of effect. Significant impact on CO_2 emissions from agriculture have the numbers of animals (respectively cattle units). In the case of applications reviewed model from the Czech Republic to selected countries of the EU shows that the highest investment costs and also decrease CO_2 equivalent emissions from agricultural biogas plants is in Germany. The high number of agricultural biogas plants is also evident in Italy and the United Kingdom. Investment costs are in these two countries in the range of 115 to 144 mld. CZK. Furthermore, it is evident that the significant investment costs are incurred by the smaller countries (Czech Republic, Slovakia, Belgium). Investment costs in this case are in the range 10-33 mld. CZK.

Keywords

Introduction

Because of significant increase in greenhouse gas emissions in the last decades, the pollution has become central global problem. Several countries including EU member states signed Kyoto protocol, which brings compulsory responsibilities. European Union declared to decrease greenhouse gas emissions by 20% on average compared to the level of 1990 by 2020. One of the tools to achieve this goal is to increase the share of renewable resources in energy mix by 20% by 2020 (EEA 2013).

There are many factors influencing the level of CO_2 emissions. The economic grows, number of inhabitants, technological changes, subsidies, institutional structures, transport, life style, international trade etc. are some of these determinants (Escolano and Rosa, 2005).

Agriculture generally including animal production significantly contributes to greenhouse gas emissions (Bellarby et al., 2013, Galloway et al., 2007, Herrero et al., 2011). As a result of this influence the agriculture community has undertaken to decrease emissions, which will lead to better environment protection. Over all agriculture emissions are 5,4-5,8 $GtCO_2e$, which is approximately 12% of total anthropogenic emissions (Tubiello et al., 2013).

When evaluating agriculture emission structure approximately 38% are accounted to nitrous oxid (N_2O) from soil, 32% from ruminants (CH_4), 12% from biomass burning, 11% from rice production a 7% from manure management (Bellarby et al., 2008).

Majority of studies focuses on reduction of only one or several main types of greenhouse gas emissions from agriculture e.g. CH_4 in publication by Petersen et al., 2005, N_2O by Dämmgen a Hutchingsem 2008, ΔC by Scott et al., 2002, CO_2 from fossil fuels researched by Dalgaard et al 2001. Another

possibility to reduce greenhouse gas emissions is to produce bioenergy (Jørgensen et al, 2005).

In the future it is possible to expect (according to individual predictions) an increase in agriculture product demand as a result of population growth, income growth and last but not least changing dietary preferences (higher meat, dairy product etc. consumption namely in Africa, South America and Asia). There have been many studies evaluating current and future situation, nonetheless specific conclusions vary according to chosen areas or agriculture practices taken into account (Yamaji et al., 2004, Oenema et al., 2005, Herrero et al., 2008).

Agriculture and mainly animal production is in global scale one of the most significant environmental polluters (Steinfeld et al., 2006) and biggest contributor to greenhouse gas emission increase (GHG), which causes climatic changes (Johnson et al., 2007).

Impact on emissions using animal waste in biogas plant is calculated, for example in Nigeria, where the use of animal waste amounted to a total production of 1,62x109 m3 of biogas. Such a usage represents a decrease emissions by 683 ths. tonnes of CO_2 per year. (Adeoti, Ayelegun and Osho, 2014)

Most emissions is currently produced by China. In rural areas of this state used by individual households small BPS (fermenter volume to 8 m^3). Zhang, Wang and Song (2013) point to the fact that just the use of renewable resources (biogas) can represent the reduction potential of 1.25 tonnes of CO_2 per household.

European commitment to reduce their emissions is a good opportunity for change in the share of individual sources in total energy production. In Sweden the use of biogas plants with a total production of 39 GWh per year have reduced CO_2 emissions by 32 ths. tonnes / year (if the classic coal plant was replaced by this power). (Amiri, Henning and Karlsson, 2013)

Individual instructions above to reduce emissions (mainly from agriculture) are very interesting from the point of view of environmental protection, on the other hand, are very expensive investment. For example, in India, in the years 2010-2011 was invested to the renewable sources 19 mld. dollars. Decrease in emissions due to these significant investment is estimated at 203 mil. tonnes of CO_2 at an installed capacity of 24 GW in 2012. (Mahesh and Shoba Jasmin, 2013).

Paper focuses on biogas stations (BGS) influence on CO_2 emissions based on presumptions stated in methodology. In the future biogas will have increasingly higher importance as a factor leading to greenhouse gas emissions degrease, considering optimal cost oriented usage of possible sources and technologies. The results of studies imply the fact that it is an ideal combination of electricity and heat production mainly in the area of agglomeration or industrial enterprises. With this necessary condition it is possible (according to calculation based on life cycle - LCC, LCA) to save 198 Euro per 1 ton of CO_2 equivalent using biogas instead of fossil fuels (Rehl, Muller, 2013).

The main goal of this paper is to determine the effect of the investment costs to biogas plants on the amount of emissions of equivalent of CO_2 from agriculture.

Materials and methods

Econometric modelling is used for structural analysis, which derives significant factors effecting the amount of CO_2 emissions produced by agriculture production including quantification of economic variables in the form of time series.

Data sets are for the period 2002 – 2014 and concern emissions (expressed) in CO_2 for the area agriculture, and other branches in the framework of economy (energetics, industry, agriculture, LULUCF, wastes). Particular values in the area of agriculture are further (within the methodology) divided into two groups: enteric fermentation (concerning farm animals and their digestive processes), and further to the area land (concerning use of fertilizers and manure management). This key data were obtained from annual reports of CHMU for particular above mentioned groups[1].

Numbers of livestock are obtained from Czech statistical office for individual categories (cattle, pigs, chicken). Those numbers are recalculated to cattle unit tin accordance with appendix n. 1 of Bill n. 377/2013 Col.[2]

Install power is undertaken from statistics OTE, ERU[3] and investment costs are calculated in accordance to recommend values by Dvořáček

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[1] Available at web sites: http://portal.chmi.cz/files/portal/docs/uoco/oez/nis/nis_ta_cz.html

[2] available at web sites: http://eagri.cz/public/web/ws_content?contentKind=image&section=1&id=377-213c.pcx

[3] OTE - Czech electricity and gas market operator, ERU - Energy Regulatory Office

(2010), when coefficient 100 000 CZK per 1kW of install power is used.

For dynamic characterisation of chosen time series base and chain indexes including average rate of growth calculation are used.

Formula 1 – Base index $= \frac{Xi}{Xz} * 100$ (result in %) when Xz is base value

Formula 2 – Chain index $= \frac{Xi}{Xi-1} * 100$ (result in %)

Formula 3 – Geometric mean $= \sqrt[n]{x1 * x2 * x3 \dots xn}$
ADF test (Augmented Dickey – Fuller) with null hypotheses H0: data are non stationary, H1: data are stationary, was used for data evaluation in the time series form.

The principle of the test is criteria calculation, which in order to accept H0 must be higher than the critical table value. Supporting variables in the form of time series were defined as non-stationary.

The classical regression analysis usage could lead to spurious regression, but considering a short time series a cointegration analysis cannot be used and it is not possible to determine a long-term relation among variables. However, for further mentioned models it is valid that the calculated residues are stationary.

For specification and quantification of significant determinants influence, economic quantities were selected which with their presence and effect will enable to estimate models verified in all respects, from the economic, statistical and econometrical point of view. These chosen variables are a part of below mentioned econometric model (1.1).

$co2total_t = \gamma_{11} + \gamma_{12}\, invcost_t + \gamma_1\, animals_t + \gamma_{14}$
$fertilizers(t\text{-}1) + u_{1t}$ (1.1)

when $u_{it} \sim$ n.i.d. (0, σ^2), for i = 1,2…

Authors will use estimations of the linear functions in the work. The estimations of linear function serves as an expression of direction and intensity of effect of predetermined variables from absolute viewpoint.

The submitted work defines several presumptions which it would like to confirm or rebut with the use of a linear regression model which will be applied in a structural analysis of air pollution measured with kt equivalent of CO_2 coming from activities in non-agricultural area.

P1: growing cost investment to agricultural biogas stations (variable invcostt) will have a significant

positive effect on pollution which will be shown by reduction of pollutants in the air,

P2: numbers of farm animals are a very important factor which will increase emissions Conversion to cattle units according to EAGRI Conversion of farm animals to a big cattle unit (cows, pigs, poultry) was realized according to coefficients published on web sites of the Ministry of Agriculture (appendix n. 1 of Bill n. 377/2013 Col.).

P3: an amount of used fertilizers in last period will have greater effect on the air pollution than numbers of farm animals because we can expect time delay between the usage industrial fertilisers and increase in CO_2 emissions.

Subsequently, the estimated model used for comparison of emission reductions in selected EU countries (Austria, Belgium, France, Germany, Italy, Slovakia, Hungary, Great Britain and Poland). Investment costs in different countries are calculated according to the installed capacity, using the coefficient (1 kW = 100 ths. CZK). Reducing emissions is calculated based on results for the Czech Republic, which are (ceteris paribus) be applied to other selected countries.

Results and discussion

The CO_2 emission development in Czech Republic in accordance with biogas station construction (Graph 1) is possible to describe by elementary characteristics, chain and base indexes with initial year 2002. Their results are in Table 1.

With the help of chain index detecting interannual changes of individual data according to average rate of growth, we can detect almost 44% increase of investment costs. It is clear, that this situation occurs after implementation of EU fund subsidies. The fast rate of growth is in this case supported by decision of ERU (Energy Regulatory Office) concerning purchase prices and green bonuses of this renewable resource. Biogas stations connected to the end of 2011 obtain 4120 CZK per 1 MWh (purchase price). Biogas stations connected from 1.1.2012 till 31.12.2012 obtain the sum of 3550 CZK per 1 MWh (purches price). Larger biogas stations (over 550 kW of installed power) have from 1.1.2013 purchase price only 3040 CZK per 1 MWh. As a result of significant increase in renewable recourses (solar, wind etc.) there are no set purchase prices of electricity for biogas stations connected in 2016. Unambiguously positive and different development
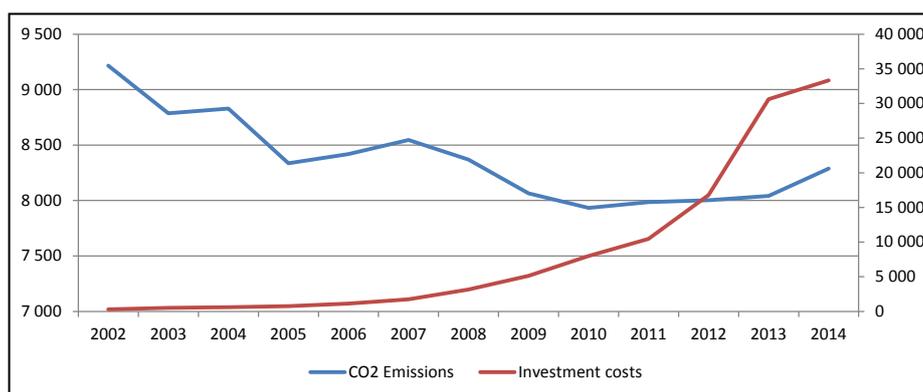
Source: Authors - own processing

Graph 1: Development of emission in kt CO_2 eq. and investment costs on BGS in mil. CZK.

chain index	base index	chain index	base index
Investment cost	Investment cost	CO_2 emissions	CO_2 emissions
1.73630137	1.73630137	0.953411	0.953411
1.17357002	2.037671233	1.004978	0.958158
1.253781513	2.554794521	0.943955	0.904458
1.516085791	3.873287671	1.010084	0.913579
1.532272325	5.934931507	1.014992	0.927276
1.828043855	10.84931507	0.979354	0.908132
1.617424242	17.54794521	0.963691	0.875158
1.56323185	27.43150685	0.983665	0.860863
1.30474407	35.79109589	1.006624	0.866565
1.604344082	57.42123288	1.002025	0.86832
1.825251983	104.8082192	1.004844	0.872526
1.089367403	114.1746575	1.030661	0.899278
Geometric mean		Geometric mean	
1.439708583		0.991867	

Source: Author – own calculation

Table 1: Changes of investment costs and CO_2 emissions in time.

can be detected for emissions, which decreased on average by 1% in the actual period.

Before estimation of specific linear regression model multicolinearity between explanatory variables was detected with the help of correlation matrix. It proved high measure of association between investment costs and fertilizers and between number of livestock and fertilizers.

In this case it is not possible to separate individual variable influence and their effect is collective. This conclusion corresponds with the fact, that animal and plant production are closely connected. With the help of VIF test multicolinearity problem was confirmed for variables costs and fertilizers. The value of test criteria VIF exceeded recommended number 10. Model estimations stated in Table 2 take into account detected

1st order negative autocorrelation of residual by heteroscedasticity and autocorrelation consistent errors (hac errors).

From economic point of view investment costs growth confirm presumption P1, which was stated in methodology of work, but statistic verification speaks about inversion. The variable does not have statistically significant effect, despite of this influence direction being correct. If investment costs to biogas stations increase, CO_2 emission decrease. The only significant parameters appear to be according to presumptions animal numbers and quantity of fertilizers one year before. From introduced results it is not possible to interpret, which variable has the most significant effect on CO_2 changes caused by multicolinearity. One of possibilities how to remove unwanted multicolinearity influence

	coefficient	standard error	t-share	p-value	
const	957.565	1289.25	0.7427	0.47889	
	-0.00397	0.00649	-0.6103	0.55858	
animals	0.00298	0.00024	12.4650	<0.04304	***
fertilizers_1	9.6471	4.036	2.4021	0.00001	**

Note: Dependent variable: co2total
  Coefficient determination 0.942
  Adj. coefficient of determination 0.891
  D-W statistics 3.212
Source: author – calculations in the software Gretl

Table 2: Estimation of linear regression model.

	coefficient	standard error	t-share	p-value	
const	4905.2	803.331	6.1061	0.00049	***
d_invcost	−0.00296	0.01593	-0.1857	0.85796	
animals	0.002013	0.000472	4.2682	0.00371	***
d_fertilizers_1	8.21751	5.46888	1.5026	0.17664	

Note: Dependent variable: co2total
  Coefficient determination 0.82
  Adj. coefficient of determination 0.75
  D-W statistics 1.57
Source: author – calculations in the software Gretl

Table 3: Estimation of linear regression model after multicolinearity removal.

is primary data transformation to first differences form. It was provided for variable investment costs and fertilizers. Conditioned variables in correlation matrix and VIF test do not prove multicolinearity anymore.

Newly estimated model, which results are in Table 3, provides information which can be interpreted individually. Variable investment costs were included in the model as a significant explanatory variable. In this period was proved, that this variable is statistically insignificant. For this reason, this variable (investment cost) in not further interpreted. It is possible to say, that unit increase of animal number causes the increase of CO_2 emissions by 0.002013 kt. Construction and good management of BGS unambiguously support the elimination of pollutions in the greenhouse gas form arising from animal production. Expressed relatively in the form of elasticity Table 4 shows that increase of animal unit by 1% brings increase of emissions by almost 0.5%.

	Elasticity in %
BGS	−0.0031
animals	0.41
fertilizers	0.25

Source: Author – own calculation

Table 4: Elasticities estimation of total CO_2 emissions model.

Based on the verified model for the Czech Republic is also made a comparison with selected EU countries. The calculation is based on the calculation of investment costs in other countries (calculation is according with the methodology) then is estimated emissions reductions based on the results of the Czech Republic (see Table 5).

	Investment cost (mil. Kč)	Impact on emissions CO_2 from agriculture (kt)
Austria	8100	-23.9760
Belgium	17820	-52.7472
France	29720	-87.9712
Germany	385900	-1142.2640
Hungary	6140	-18.1744
Poland	20930	-61.9528
Italy	115470	-341.7912
Slovakia	10170	-30.1032
United Kingdom	144000	-426.2400
Czech Republic	33339	-98.6834

Source: Author – own calculation

Table 5: Investment cost and their impact on emissions in selected countries EU (2014).

The results show that the sharpest reductions takes place in Germany (a fall of 1142 kt CO_2 equivalent emissions). In this country the biogas plant is widespread, it is also interesting value investment costs (100 ths. CZK per 1 kW of electricity),

amounting to 386 mld. CZK. The high number of agricultural biogas plants is also evident in Italy and the United Kingdom. Investment costs in these two countries, ranging from 115 to 144 mld. CZK. Table 5 shows that the significant investment costs are incurred by the smaller countries (Czech Republic, Slovakia, Belgium). Investment costs in this case are in the range 10-33 mld. CZK.

Conclusion

Exponential growth of investment costs for BGS construction and their quantity was impulse for researching this situation and looking for main determinants effecting them. With the help of chain index detecting interannual changes of individual data according to average rate of growth, we can detect almost 44% increase of investment costs. It is clear, that this unsustainable situation occurs after implementation of EU fund subsidies. Unambiguously positive and different development can be detected for emissions, which decreased on average by 1% in the actual period.

Since 2005, EU has managed to decrease its aggregated emissions by 3.1%. But, the results from this study show, that each EU member state performs very differently in emissions intensities. Even more, the emission intensity results show an alarming tendency of increase in most of the EU member states, which indicates that the measured changes in aggregate agricultural emissions rates are misleading. (Dace and Blumberga, 2016)

In Italy consider of mathematical modeling of the impacts of greening (recent CAP reform 2014–2020). In this study they estimated the potential environmental benefits from greening in terms of GHG emissions in four regions of Northern Italy. The model estimates a reduction in CO_2 emissions of about 2%. Emissions from nitrous oxide show a decrease of 2.1% and the reduction in the methane is about 0.4% compared to the observed scenario. (Solazzo et. al., 2016)

From economic point of view investment costs growth confirm presumption P1, which was stated in methodology of work, but statistic verification speaks about inversion. The variable does not have statistically significant effect, despite of this influence direction being correct. If investment costs to biogas stations increase, CO_2 emission decrease. The only significant parameters appear to be according to presumptions animal numbers and quantity of fertilizers one year before.

From introduced results it is not possible to interpret, which variable has the most significant effect on CO_2 changes caused by multicolinearity. Therefore it is not possible to react adequately to presumption P2 and P3.

Newly estimated model, which results are in Table 3, provides information which can be interpreted individually. It is possible to say, that unit increase of animal number causes the increase of CO_2 emissions by 0.002013 kt. Construction and good management of BGS unambiguously support the elimination of pollutions in the greenhouse gas form arising from animal production by using their waste. Expressed relatively in the form of elasticity Table 4 shows that increase of animal unit by 1% brings increase of emissions by almost 0.5%. It is possible to evaluate the reaction as non elastic. Number of livestock significantly influence emission quantity however their forceful decrease does not come to effect in the end.

Suitable technology for animal and plant waste management can provide sources for plant production which does not need to use mineral fertilizers to such extend. In this case sludge (liquor) and digestate from biogas stations is used. According to legislation digestate is type organic fertilizer if it complies with the condition of minimum of 25% burnable matter in dry substance and minimum content of nitrogen 0.6% in dry substance and it falls into the category of fertilizers with rapid release nitrogen.

Usage and digestate dose as fertilizer is comparable to slurry considering the amount of nutrients mainly nitrogen. Similar principles defined for fertilizing with liquid organic fertilizers are valid for their application. (Fuksa and Hakl, 2009)

Construction of BGS is long time investment which becomes profitable approximately in ten years. Mužík and Abrham (2006) consider the return rate of investment in 5 years to be very good, in 10 years to be acceptable. This results are confirmed by other studies by Wu et. al, 2016; Mel et. al, 2015 or Kang et. al, 2014. If animal production is further reduced and unstable situation namely in milk production is deepened, the question is whether this initially valuable idea does not paralyse the agriculture enterprises in the future.

In the case of applications reviewed model from the Czech Republic to selected countries of the EU shows that the highest investment costs and also decrease CO_2 equivalent emissions from agricultural biogas plants is in Germany.

The high number of agricultural biogas plants is also evident in Italy and the United Kingdom. Investment costs are in these two countries in the range of 115 to 144 mld. CZK. Furthermore, it is evident that the significant investment costs are incurred by the smaller countries (for example Czech Republic, Slovakia and Belgium). Investment costs in this case are in the range 10-33 mld. CZK. In the framework of the emission reduction is CR 4th place (-98 kt CO_2 equivalent) after Germany (-1142 kt CO_2 equivalent), United Kingdom (-426 kt CO_2 equivalent) and Italy (-341 kt CO_2 equivalent).

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