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IMPACT OF BIOGAS STATIONS ON CO_2 EMISSION FROM AGRICULTURE

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Abstract

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This paper deals with the effects of biogas stations on CO_2 emissions produced within agricultural sector. In last years, owing to a positive policy of renewable energy resources a number of biogas stations in the CR has rapidly increased – actually over 350 agricultural biogas stations with the total installed power 365 MW are in operation. Concerning CO_2 emissions from the agricultural sector, there is a presumption of decrease in produced emissions owing to decrease of influence of animal wastes which are processed just in the biogas stations. From the results it is obvious that CO_2 emissions produced by agriculture in the CR decrease by 93.7 thousand tonnes annually. A presumption P1 that building of biogas stations will further support this trend is documented with results of a simple dynamic linear regression model. Further, elasticities of particular variables influencing the total emission from agriculture are investigated in the paper.

Keywords: biogas stations, CO_2 emissions, greenhouse gases, agriculture, numbers of animals, fertilizers, linear regression model

INTRODUCTION

Energy is a key element in human life. Sufficient and available energy supplies are very important for sustainability of modern type of society. Requirements for provided energy grow fast all over the world and this trend will together also continue in the future (with a population growth). Today, the energy is obtained from various sources which can be generally divided into renewable and non-renewable. In more detailed view of electric power production over 20 thous. TWh have been produced in the world scale. Of this sum, 40 % come from coal, 20 % from natural gas, 16 % from nuclear power supply, 16 % from water power stations, 7 % from crude oil, and only 2 % from renewable resources (water, wind, geothermal etc.) (Muneer, Asif and Munawwar 2005).

Based on prognoses of the future development in a report “World Energy Outlook” a worldwide increase of renewable energy resources is expected at the expense of decrease in electric power production from coal (which is now the dominant production resource). A share of renewable resources according to thise prognoses will grow in the world scale at a level exceeding 20 % (year 2030). This trend appears also in IPCC reports when a necessity of stabilisation of CO_2 emission in energy production is stated to prevent catastrophic scenarios of climatic changes (IEA, 2011; IPCC, 2013).

Renewable energy resources grow faster now than the growth of total energy market. Some long-term scenarios suppose fast-growing share of renewable technologies (which are composed from sun, wind, geothermal, and biomass energy, modern as well as traditional resources, i.e. water.). According to these scenarios, the renewable resources should reach the amount of 50 % of the total energy consumption till the half of 21st century with appropriate policies and new development technologies (Akella, Saini and Sharma, 2009).

From a viewpoint of anthropogenic emissions of green-house gases, CO_2 represents the main part of emissions, it creates 80 % of greenhouse gas emissions. The Czech Republic belongs to smaller countries (it concerns absolute numbers of CO_2 emissions), however, looking closer at emissions of greenhouse gases per inhabitant we find out that the CR is an important polluter of air (Czech Republic see Fig. 1). The highest values are reached by Qatar (55 tonnes per inhabitant/year).

There are many factors affecting the level of CO_2 emissions – the economic growth, the growth of population number, technological changes, endowment sources, institutional structures, transport, life style, international trade et. (Escolano and Rosa, 2005).

At this time, agriculture represents approximately 14 % of total global emissions of anthropogenic greenhouse gases and at the same time agriculture is responsible for 47% and 58 % of the total emissions of methane and nitrogen monoxide. Methane is produced by anaerobic decomposition of organic substances above all in connection with enteric fermentation of ruminants. Other important source in the world are rice growing and also storage of farm fertilizers. The CO2 emissions from agriculture are connected with the use of organic and mineral fertilizers (nitrogen, phosphorus, potassium) applied in the land fund (eventually with storage of organic fertilizers) (Rees *et al.*, 2014).

From 1990 to 2005 production of methane and nitrogen monoxide increased almost by 17 % (average yearly growth 60 Mt CO_2 equiv. (IPCC, 2007). However, the size and relative significance of sources differ considerably among particular regions (70 % of increase of agricultural emission fall on developing countries) (Stern, 2006).

In the future, an increased demand for agricultural products is expected owing to population growth, income growth, and changing catering preferences (increased consumption of meat, milk products – it applies above all to Asia, South America, and Africa).

For evaluation of the present and future situation many studies dealing with these problems have been made, however, particular conclusions considerably differ. Particular works focus on selected agricultural regions and agricultural activities (e.g. Yamaji *et al.*, 2004; Oenema *et al.*, 2005; Herrero *et al.*, 2008.)

Agriculture and mainly the animal production is in the world scale one of the main driving forces of pollution of environment (Steinfeld *et al.*, 2006) and the main contributor to a rise of greenhouse gases (GHG) causing climatic change (Johnson *et al.*, 2007).

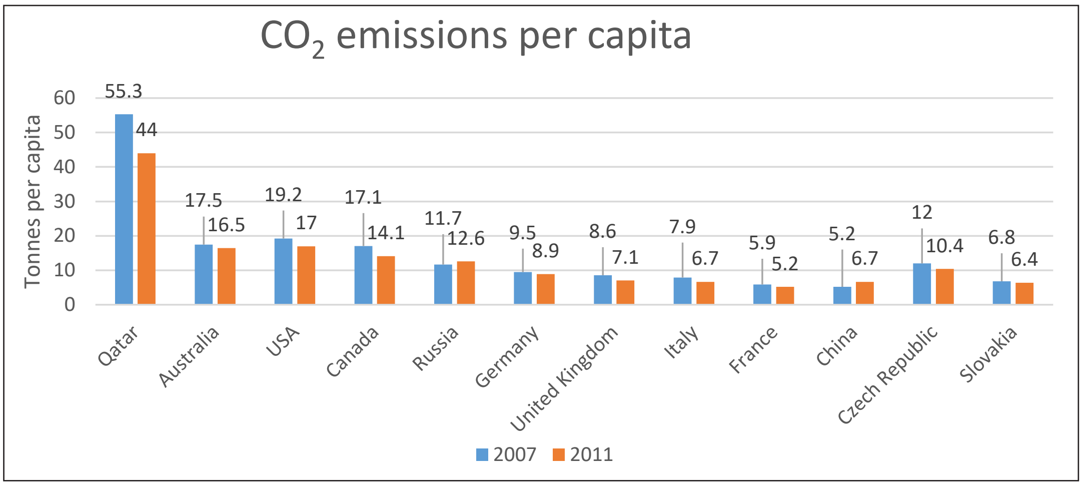
Particular productions of agricultural activities connected with greenhouse gas emissions influence each other. Methane emissions from manure storage or enteric fermentation owing to increased animal production have to be completed with emission of nitrogen monoxide from land due to increased production of raw materials (Thorpe, 2009).

Identification of kinds and sources of CO_2 emissions and their size are fundamental information for future planning and decision making of particular competent authorities

Mitigating alternatives of emission of greenhouse gases from agriculture are particularly important mainly in order to enable further sustainable development and at the same time to stabilize emissions of greenhouse gases together with global average temperature with regards to aims of Kjóto protocol from 1997 and Copenhagen Accord in 2009. For example Denmark undertook to decrease greenhouse gas emissions by 20 % by 2013 (Houghton, 2004).

Most studies focus on mitigation of only one or several main types of emissions of greenhouse gases from agriculture (for example CH4 by Petersen *et al.*, 2005; N2O by Dämmgen and Hutchingsem, 2008; ΔC Scott *et al.*, 2002; CO2 from fossil fuels by Dalgaard *et al.*, 2001; or possibilities of mitigation through bioenergy production – Jorgensen *et al.*, 2005).

This papers disserts on effect of biogas stations on CO_2 emissions based on presumptions introduced in the methodology. Biogas will have bigger and bigger significance in the future as a factor in reduction of greenhouse gas emissions regarding cost-optimal use of available resources and technologies. From



1: *Amount of CO_2 emissions per inhabitant in selected countries (2007, 2011, t)*
Source: World Bank (2014)

results of the study a fact arises that the ideal combination is production of electricity and heat near agglomerations or industrial enterprises. With this condition it is possible (according to calculation on base of life cycle – LCC, LCA) to save as many as 198 Euros on 1 t of CO_2 equivalent in exchange of biogas for fossil fuels. Purification and injection of modified biogas in a natural gas system can save as many as 72 Euros for 1 t of CO_2 equivalent (Rehl, Muller, 2013).

MATERIALS AND METHODS

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

Data set are for the period 2000–2014 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 (it concerns farm animals and their digestive processes), and further to the area land (it concerns use of fertilizers and manure management). This key data were obtained from annual reports of CHMU for particular above mentioned groups.

Presumption time series stationarity was evaluated by ADF test (Augmented Dickey – Fuller). ADF test defines null hypothesis suggesting that time series are non stationary. The base of the test is criteria quantification, which in order to accept null hypothesis must be higher than the critical table value. Supporting data in the form of time series were evaluated as non-stationary.

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

$$co2total_t = \gamma_{11} + \gamma_{12} bps_t + \gamma_1 animals_t + \gamma_{14} fertilizers_t + u_{1t} \quad (1.1)$$

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

Authors will use estimations of the linear functions in the work. The estimations of linear function serves for 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 equivalent of CO_2 coming from activities in non-agricultural area.

For calculation of particular models, data of the Czech Hydrometeorological Institute were used[1]. Further, data (NIR) were used processed for European monitoring (KONEKO, CDV, CHMI, IFER, CUEC), where particular components of emissions from agriculture are divided in several subgroups (it is dealt with A) enteric fermentation, B) manure treatment, V rice growing, D) use of fertilizers on agricultural land, E) managed fire). Groups C + E were not showed for the CR in used data[2]. Data about consumption of fertilizers are drawn from CzSO (Czech Statistical Office, 2000–2014). It is dealt with consumption of industrial fertilizers expressed in net nutrients.

- P1: growing number of biogas stations (variable bps_t) will have a positive effect on pollution which will shown by reduction of pollutants in the air more than 2000t/year
- P2: a very important factor which will increase emissions are numbers of farm animals

  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 (eagri.cz, precept No. 20/supplement No. 1).
- P3: an amount of used fertilizers will have double effect on the air pollution than numbers of farm animals

Other used time series are values of used fertilizers in agriculture. These data were found out on the web sites of Czech Statistical Office (CzSO), use of fertilizers were found at VURZ (Crop Research Institute).

Agriculture is the main source of ammonia which originates mainly from excrements of farm animals. Other source of emissions is an application of inorganic nitrogenous fertilizers on land. For this reason time series of a number of farm animals and amount of embedded nitrogenous fertilizers in land are used in this paper. Increase of outflow of nitrogen from land is possible for example in these ways: outflow of nitrates, nitrification, denitrification.

Growing emissions of reactive form of nitrogen in the environment is one of serious environmental problems. In this case, the main motive power is N_2O which originated just for example by denitrification

1 available at web sites: http://portal.chmi.cz/files/portal/docs/uoco/isko/grafroc/groc/gr12cz/tab/t122.html
2 available at web sites: http://www.chmi.cz/files/portal/docs/uoco/oez/nis/NIR/NIR-2011-2009-CZ-UNFCCC.pdf

of nitrates from fertilizers. This greenhouse gas is 298 times more harmful than CO_2. (Moldan, 2015)

For above mentioned model coefficients of elasticity are calculated by the help of an exact method according to the formula 1.2 which use estimated function norms and supporting data.

Models with selected variables will be tested in order to fulfill all presumptions about a random component including specification presumptions of the whole linear-regression model. After that it is possible to consider the estimations of structural parameters to be the best, impartial and consistent. The models will be estimated with the use of econometric software Gretl for supporting data in form of time series for the period 2000 – 2014.

RESULTS AND DISCUSSION

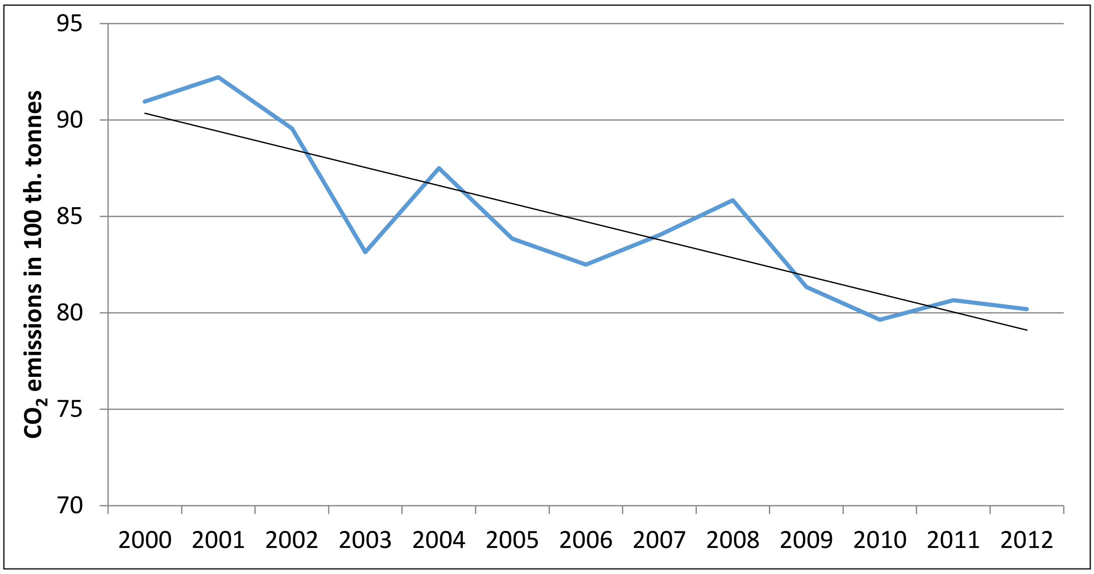
Further part of work is creation econometric model with the aim to determine whether growth of a number of biogas stations in the CR affects the amount of emissions caused in the agriculture. Increasing number of biogas stations uses still more and more amount of animal wastes from which CO_2 emission cannot be release.

Fig. 2 represents is it obvious that CO_2 emissions produced by CR agriculture decrease every year.

From the fitted trend function, parameters of which are introduced in the Tab. I, it results that emission decrease by 82,598 thous. tonnes on average every year. It is possible to suppose that this decrease is above all a consequence of decrease in numbers of farm animals.

The stated significant annual decrease provides approximately 1% of total emissions produced by agriculture. It is clear, that this trend is not sustainable mainly because further increase in number of biogas stations is not expected. EU subsidies are no longer realised.

A presumption that building of new biogas stations will further support this trend is documented by results of a simple dynamic linear regression model, showed in the Tab. II. According to a regression coefficient every other biogas station



2: *Development of total emissions in agriculture in CO_2 equivalent in 100 thous. tonnes (2000–2012)*
Source: author – own calculations on base of CHMU data

I: *Estimation of trend function of simple regression of total CO_2 emissions in tonnes. Dependent variable: co₂total*

	coefficient	standard error	t-share	p-value		DW stat	R^2
Const.	9.071e+06				***	1.85	0.77
time	–82598	113642	79.8202	<0.00001	***		

Source: authors – calculation in the software Gretl

II: *Estimation of linear function of simple regression of total CO_2 emissions in tonnes. Dependent variable: co₂total*

	coefficient	standard error	t-share	p-value		DW stat	R^2
Const.	8.69463e+06	105040	82.7745	<0.00001	***	0.99	0.54
bps	–2658.66	675.849	–3.9338	0.00171	***		

Source: authors – calculation in the software Gretl in the foregoing period will reduce CO_2 emission by 2658.66 tonnes in actual year.

Regarding to inconclusiveness of DW test, autocorrelation of residues of the 1st order was treated also with Breuch-Godfrey test which does not reject the zero hypothesis about absence of autocorrelation of residues. (Hušek, 2007)

CO_2 emissions from agriculture affect numbers of animals and the amount of used industrial fertilizers. From the supporting data it is clear that while numbers of animals keep decreasing, above all in cattle in the dairy cow category, but also pigs and poultry, it is possible to monitor an increase in the amount of used artificial fertilizers. This positive development is obvious mainly in a nitrogen component of fertilizer.

If we did not consider the above mentioned emission determinants, we would commit a specification error of the econometric model by non-inclusion of a fundamental explanatory variable. For this reason, a model of multiple regression which results are introduced in the Tab. III is estimated. Because a high multicolinearity between the number of biogas stations and the number of animals was found, it is right to interpret their effect not separately, but jointly.

Although a variable number of biogas stations in the model of multiple regression is not statistically verified, its inclusion improves characteristics of the model.

Coefficient determination 0.914

Adj. coefficient of determination 0.891

D-W statistics 2.088

According to the results of structural parameters of linear function mentioned in the Tab. III and IV it is possible to interpret a similar negative reaction of development of emissions in a case of increase of the number of biogas stations in the foregoing period. The results of estimations (Tab. IV) can be interpreted relatively in the following way; 1 % increase of biogas stations will reduce emissions by only 0.016 %.

Contrary to the number of farm animals where an increase in their number in the last period by 1 pieces the CO_2 emissions will increase by

III: *Estimation of linear function multiple regression of total CO2 emissions in tonnes. Dependent variable: co_2total*

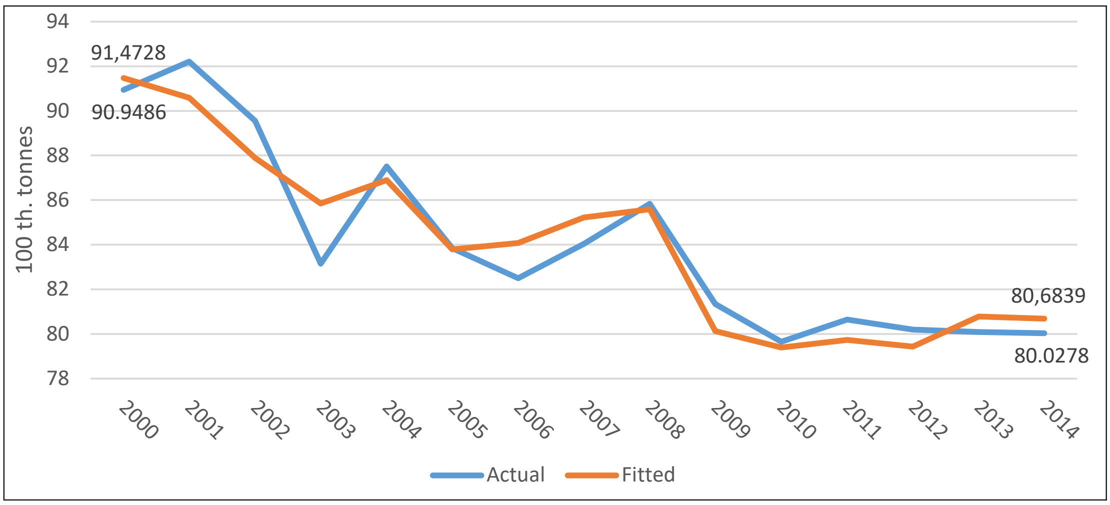
	coefficient	standard error	t-share	p-value	
const	738797	1.45824e+06	0.5066	0.62241	
bps	−1281.55	848.411	−1.5105	0.15909	
animals	3.03029	0.438071	6.9174	0.00003	***
fertilizers	13.6471	4.78125	2.8543	0.01568	**

Source: author – calculations in the software Gretl

IV: *Elasticities estimation of total CO_2 emissions model*

	Elasticity in %
bps	−0.016
animals	0.57
fertilizers	0.36

Source: own calculations



3: *Fitted and actual values CO_2 emissions from agriculture in the Czech Republic (100 thous. tonnes)*
Source: author – own calculations

3.03 tonnes. These results are confirmed also by other studies which introduce emission from 1 cow (a cattle unit) 110 – 128 kg methane. In conversion to CO_2 we get on values moving in a range 2530–2944 kg CO_2 (Bannink *et al.*, 2011).It is possible to interpret with elasticity, when one-percent change in the number of animals will change directly proportionally the amount of pollutions by 0.57 %.

However, according to estimated results the air pollution is affected more by the use of industrial fertilizers processed last year in the following way; if the fertilization increased by one tonne, then the emissions would increase by 13.6471 t, which is in relative value formulation 0,36 % according to tab. n.4. Emission of nitrogen compounds from soils are very heterogeneous in dependence on local conditions (temperature, humidity, pressure) and can move in order of units to hundreds of kilogrammes per ha/year. (Šimek, 2008; Aguilera *et al.*,2013).

Particular analyses evaluating impacts on the environment in recent years has shown the use of biogas for production of electric energy and heat produces less greenhouse gases than the use of fossil fuels (Borjesson and Berglund 2006; Edelmann at al., 2005; Jury *et al.*, 2010; Kimming *et al.*, 2011). A question in this case is whether it is possible to use arable land for agricultural production as input source for production of electricity in biogas stations. In this case it is suitable to use above all waste products of farm animals which are not always used in form of fertilizers. For this reason it would be rational to support such biogas stations which use predominantly waste products. A synergetic effect is in this direction a support to breeders of farm animals. A self-sufficiency rate in particular kinds of meat (an exception is a self-sufficiency in beef meat) is considerably below 100 % (pig meat 53 %, poultry meat 78 %) in the Czech Republic. (Slaboch and Kotyza, 2016)

For this year, supports for breeders of farm animals are allowed in form of supports for breeders of dairy cows and sows, a refund of consumption tax for fuels for breeders of cattle, pigs, poultry, sheep and goats, a support for improvement of living conditions of animals and so on.

The biggest sensitivity of change of CO_2 emissions was recorded in a number of cattle units; this variable is followed by nitrogenous fertilizers. So, an influence of number of biogas stations on emissions is negligible.

These results correspond with the fact which documents that in the last ten years there is annual decrease in the number of farm animals, both in the cattle and the pigs and the poultry, and gradual increase in use of artificial fertilizers.

CONCLUSION

CO_2 emissions produced by agriculture in the CR decrease by 82.598 thousand tonnes every year. The presumptions P1 that the building of biogas stations will further support this trend is documented by results of similar dynamic linear regression model where it is possible to state that every other working biogas station will decrease CO_2 emission by 2658.66 tonnes next year.

The presumption P1 is confirmed also by the multi-regression model where a similar reaction of emission development in case of increase of the number of biogas stations in the foregoing period was found. Every other working station will decrease the amount of emissions. The following presumption P2 can be considered verified because the estimated structural parameter of the number of farm animals can be interpreted in this way. With increase in the number of animals (cattle unit) in the last period by 1 pieces the CO_2 emissions will increase by 3.03 tonnes. However, according to the estimated results, the most effect on the air pollution is caused by the use of industrial fertilizers processed in the last year as we expect in the presumption P3. If the use of industrial fertilizers increased in a common period by 1 tonnes of net nutrients, then the emissions would grow by 13.6471 tonnes. This high increase is caused by emission of N_2O which is in comparison with CO_2 298 times more harmful.

The interpreted results of elasticities document that 1 % increase of biogas stations will reduce emission by only by 0.016 %; one-percent change of the number of animals will change directly proportionately to the amount of pollutants by 0.57 %, and the used fertilizers in the same direction will affect the investigated variable by 0.36 %.

This article is the basis for further detailed exploration of the reduction of emissions in individual companies operating with biogas stations.

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