THE ECONOMIC VIABILITY OF THE ENERGY PRODUCTION FROM BIOMASS VIA ANAEROBIC DIGESTION

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Abstract: *Anaerobic digestion is a microbial process that occurs in the absence of oxygen where a community of microbial species breaks down both complex and simple organic materials, ultimately producing methane and carbon dioxide. Biogas refers to a secondary energy carrier that can be produced out of many different kinds of organic materials and its options for utilization can be equally versatile - biogas can be used to generate electricity, heat and biofuels. It is clear that introduction of the subsidies in 2009 for BGPs initiated usage of the AD technology for generating electric energy. The sharpest increase in number of BGPs was recorded in 2013; however, there was a major downsizing in their installation in 2014 due to change in the subsidy system. The main aim of the paper is to forecast economic viability of biogas plants in Slovakia based on the net present value indicator, estimation of payback period of the technology and assessment of the maximum economic price of input material.*

Keywords: *Biogas, Net present value, Slovakia.*

1. INTRODUCTION

"Anaerobic digestion is a microbial process that occurs in the absence of oxygen. In the process, a community of microbial species breaks down both complex and simple organic materials, ultimately producing methane and carbon dioxide" (Engler et al., 2013). European Biomass Association (2013) defines biogas as a secondary energy carrier that can be produced out of many different kinds of organic materials and its options for utilization can be equally versatile. Biogas can be used to generate electricity, heat and biofuels. Also, the fermentation residues, called digestate, can be used for example as a fertilizer. Pepich et al. (2010) describe biogas as a product of transformation of biomass into energy via an anaerobic digestion (AD), where the resulting product is a biogas, serving as fuel for cogeneration units and it reaches about 70% of the energy content of natural gas. 2 178 kWh of electricity or 11.4 GJ of heat can be obtained by burning 1 000 m^3 of biogas. Additionally, 1 m^3 of biogas contains as much energy as 0.6 to 0.7 dm^3 of fuel oil for heating. Compared with conventional heat and electricity, up to 40% of fuel can be saved. Compressed and adjusted biogas can be supplied to the grid as natural gas and only additional costs for treating biogas are the barrier, even though there are already developed technologies for such treatment (Holm-Nielsen et al., 2008). Baxter (2014) points out that there are many ways how to realise flexible output produced by biogas plants. It is possible to store biogas with storage capacity locally and also via pipelines connecting more biogas plants. Excess capacity cogeneration or combined heat and power (CHP) units might be used in times of deficit irregular renewable electricity generator or of the highest demand.

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There is a concept of many biogas plants linked together for flexible operation created already. Another alternative is to upgrade biogas to natural gas quality.

Braun et al. (2014) believe that economic viability of the energy production from energy crops is possible only if we achieve high crop and biogas yields while keeping investments, raw material and production costs low. In addition, other incentives are provided like subsidies and feed-in-tariffs to increase economics of the process. Gebrezgabher et al. (2010) underline that the financial viability of the system also depends on transport of input materials. Some researchers indicate that maximum economical distance is of 15–25 km. Logistics of inputs and outputs are crucial indicator for biogas system to be economically, environmentally, and socially viable. Long distance transportation generates transportation cost as well as environmental costs in form of GHG emissions, odour and noise. Therefore, these externalities of the transport should be managed to their minimums. Wellinger (2014) states that biogas plant operators have to deal with security of sustainability of producing biomass and its higher yields per hectare via catch crop or multiple cropping on arable land. Other possibilities are permanent grasslands. There are also mechanical, physical and biochemical pre-treatment techniques to raise efficiency of biomass degradation. On the other hand, Dollhofer (2014) reminds that these mechanical and chemical pre-treatment techniques come hand in hand with significant energy loses as they require high energy input.

The paper intends to forecast economic viability of biogas plants in Slovakia based on the net present value indicator, estimation of payback period of the technology and assessment of the maximum economic price of input material. The contribution of the paper is twofold. First, the paper provides analysis of biogas sector over specific time period in Slovakia. Second, the paper gives an empirical evidence of the economic viability of the biogas sector and its benefits for investors by using simplified model of a biogas plant scenario as a representing sample.

2. MATERIALS AND METHODS

In order to forecast economic viability of biogas plants in Slovakia, the following steps are done:

Step 1: Biogas plant model is constructed on the basis of analysis of Slovak biogas sector and literature review.

Step 2: Grain maize annual price (EUR) forecast is performed. In order to predict the values, the VECM model is performed based on the long run relationship between grain maize annual prices (EUR) and amount of maize production (tonnes) in Slovakia from 1993 to 2018; data were used from Food and Agriculture Organization of the United Nations (FAOSTAT). Anderson et al. (2002) explain that VECM is a policy-oriented vector autoregressive model that is anchored by long-run equilibrium relations suggested by economic theory and VECM forecasts are considerably more accurate than simple random-walk alternative. Gangopadhyay et al. (2016) suggest that VECM indicates a nx_1 vector of stationary time series (y_t) in terms of constant, lagged values of itself and error correction term. The standard VECM model can be expressed as follows:

$$\Delta y_t = c + \varphi_1 \Delta y_{t-1} + \varphi_2 \Delta y_{t-2} + \ldots + \varphi_p \Delta y_{t-p} + ECT_t + \varepsilon_t \qquad (1)$$

where *ECT* refers to the Error Correction Term - a product of an adjustment factor (α) and the cointegrating vector (β). The cointegrating vector shows the long-term equilibrium relationship between the examined variables while the adjustment factors indicate the speed of adjustment towards equilibrium in case there is any deviation.

Step 3: Prediction of grain maize annual yields (tonnes/hectare) for following calculation of grain annual yields of grain maize (bushels/tonne). Sample Mean method is used to forecast grain maize annual yields. The formula is as follows:

$$F_{t+1} = \frac{1}{n}\sum_{1}^{n} Y_t \tag{2}$$

where F is a forecasted value in year t; n is number of observations and Y_t is an actual value in year t. The data were taken from Food and Agriculture Organization of the United Nations (FAOSTAT).

Step 4: Annual grain yields of grain maize (bushels/tonne) are estimated on the basis of its relationship with grain maize annual yields (tonnes/hectare) given by approximate bushels of grain content in a tonne of corn silage (Lauer, 2005; as cited in Lippert, n.d.). Table 1 depicts approximate bushels of grain contained in a tonne of corn silage. Data were used from Food and Agriculture Organization of the United Nations (FAOSTAT).

Table 1. Approximate bushels of grain contained in a tonne of corn silage

Maize Yield Bu/A	**Grain Yield Bu/T**
25	3,5
50	5,5
75	6,8
100	7,5
125	7,9
150	8
175	7,9

Source: Lauer, 2005 (as cited in Lippert, n.d.)

Step 5: Calculation of future maize silage annual prices derived from grain maize prices and grain yield of grain maize forecast. The formula is as follows:

$$Maize\ silage\ price_t\ (EUR / tonne) = M_t\ (EUR / bushel) * C_t\ (bushels / tonne) \tag{3}$$

where M is a price of grain maize in year t and C is a grain yield in one ton of maize in year t.

Step 6: Net present value (NPV) is used as valuation criteria in order to forecast economic viability of biogas plants and Payback Period is performed as a tool that compares revenues with costs and determines the expected number of years required to recover the original investment. NPV determines the present value of an investment and represents sum of estimated future cash flows in today’s value of money (Mészáros and Jašňák, 2014). The formula is as follows (Patinvoh et al., 2017):

$$NPV = -\mathrm{I} + \sum_{t=1}^{n} \frac{\mathrm{CF_t}}{(1+r)^t} \quad (4)$$

and

$$CF_t = p_t o_t - c_t m_t - FC_t \quad (5)$$

where CF is estimated cash flow in year t, r is discount factor and I is the initial investment. CF is a function of income, variable cost and fixed costs in year t. P is price of output, o is amount of output produced at time t, c is cost of input and m is amount of input in year t. FC are fixed cost including annuity, labour costs, G-component, manipulation with materials services, maintenance and service costs.

The following formula for Payback Period (PBP), that calculates the time required for the payback of investment, can be used for even cash inflows of a project (Santadkha and Skolpap, 2017):

$$Payback\ Period = (Original\ Investment)/(Annual\ CF) \quad (6)$$

However, if the cash flows of a project are uneven, the payback period is computed by adding the annual cash flows until such time as the original investment is recovered.

Step 7: To find out the ceiling price of the maize silage as the input for AD, Break Even Analysis was used. The ceiling price of the input is calculated at the point when total costs equal total revenues. The formula is as follows (Weil and Maher, 2005):

$$TR = VC + FC \quad (7)$$

and

$$TR = A * C + FC \quad (8)$$

where TR (Total Revenues) = cumulated quantity of electricity produced during lifetime of the project MW * guaranteed selling price of the electricity EUR / MW; VC (Variable Costs) = cumulated amount of maize silage used for AD during lifetime of the project (A) in tones * price of maize silage (C) EUR / ton; FC (Fixed Costs) = cumulated fixed costs during lifetime of the project including investment, capital costs, labour costs, G-component, service and maintenance costs and manipulation services costs. Then the final formula is derived as follows:

$$C = \frac{(TR - FC)}{A} \quad (9)$$

where C is ceiling price (EUR) of one ton of maize silage at which the biogas plant does not generate any profit nor loss.

3, RESULTS

In case of Slovakia, the sharpest increase in number of biogas plants (BGPs) was recorded in 2013. An increasing trend was experienced in the development of the biogas sector until 2014;

however, there was a major downsizing in their installation in 2014. It is clear that introduction of the subsidies in 2009 for BGPs initiated usage of the AD technology for generating electric energy. The trend in subsidies was slightly decreasing with stable values since January 2012 until December 2013. During this period, the majority of BGPs were lunched. In January 2014 the new subsidy policy was introduced that broke down biogas sector into 4 groups. The most popular scale of BGP (1 MW of capacity) lunched in 2014 were granted with lowest amount of purchasing price. The change in policy reflects trends in other countries with more developed biogas industry and also problems and negative externalities connected with BGPs of larger size. On the other hand, the change of subsidy policy for year 2014 highlights its volatility which means uncertainty in the sector which could be the main factor why there was not any new BGP lunched in 2014. 111 biogas stations with a total capacity of 103 MW were established in Slovakia by the end of July 2015 (109 installations in operation at the end of 2018) ("EnergiePortal", 2017). The average installed capacity of a biogas plant is 0.943 MW in Slovakia (for comparison, the average installed capacity is 0.4 MW in Germany) and the majority of them focus on the production of electricity from maize silage processing.

3.1. Forecast of economic viability of biogas plants in Slovakia

Considering the fact that there are not exactly the same BGPs, due to the fact that each BGP is tailored to a specific environment, capacity, location and etc., a general model was constructed, according to literature and analysis of biogas sector and its development, which represents majority of BGPs in Slovakia.

a. Scenario description

The plant is located nearby a farm to minimize transport cost for input and output materials. To simplify model, the plant is considered as economically autonomous entity. The plant uses 100% maize silage as an input material for wet anaerobic fermentation and was launched in 2013 due to the fact that in the very same year the most BGPs were activated. Its size is 1 MW of electric energy capacity. The input material is bought from the farm at market prices and the final output is electricity that is sold at guaranteed prices for 15 years, heat is used only for internal needs and digestate is provided to the farm for free as a fertilizer which is transported to the fields at the expenses of the farm. Manipulation with input and output materials are provided by the farm and the plant covers the costs which are estimated 500 EUR per month. The lifetime of the project is 15 years.

The project involves the initial investment of 3.5 million EUR, where 30% is financed by own capital and 70% is financed with debt with interest rate 3.2%, with maturity 10 years in monthly payments. 55% of the investment costs cover technology included in the second depreciation group with accelerated depreciation for the first two years then the technology is included in the third group (depreciation period of 8 years) with accelerated depreciation since 2015. The rest 45% of the investment is included into fourth depreciation group with accelerated depreciation and since 2015 it is included into fifth group with linear depreciation.

Operation costs cover all elements that are inevitable to keep the BGP running. Total labour costs including two personnel operators with average wage in the energetic sector in Slovakia are 1 174 EUR monthly per person. There are estimated 50 tonnes of input material each day, 335 days per year. 30 days per year the plant is out of service. Service and maintenance cost are estimated 60 thousand EUR each year. Operation costs also include expense for connection to the grid so called G-component (since 1.1.2014), which is estimated to 18 270 EUR per year. The plant operates 8 040 hours per year at 95% of its total capacity. Guaranteed price per one megawatt is 134.08 EUR.

b. Forecast of grain maize prices, grain maize yields in Slovakia and calculation of future maize silage prices

Forecast of grain maize prices for years from 2019 till 2027 is shown in Figure 1. The prices were predicted on the basis of relationship between annual price of grain maize and volume of production of grain maize in Slovakia. The forecast estimates steadily increasing trend for the grain maize price over the next years. There is also shown that the 95 percent intervals include relatively wide range of values and the actual future values may differ significantly from estimated ones and in that case following calculations might bring inaccurate deductions.

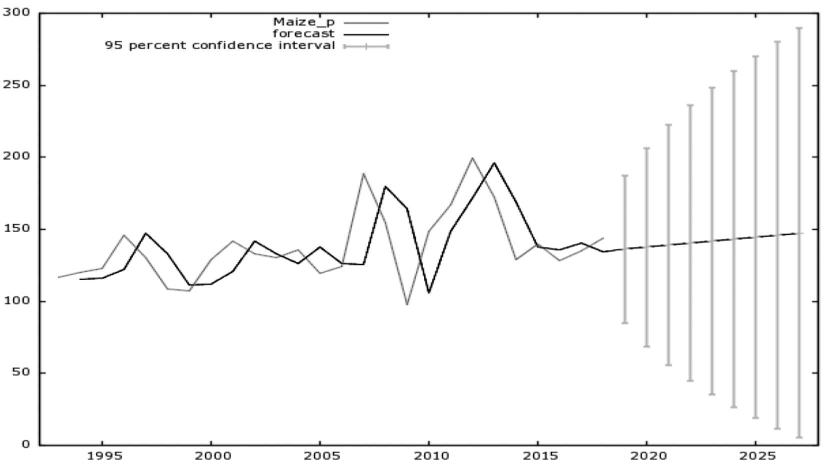

Figure 1. Grain maize prices forecast for years 2019 - 2027
Source: authors´ processing

Historical values and Simple Mean method were used to forecast yields of grain maize in Slovakia because these yields are mainly affected by weather conditions, fertilizers and pesticides usage, and technology of production. The mean value of the used data is 6.051 T/ha which is transformed into 96.39 Bu/A for next calculations (Figure 2).

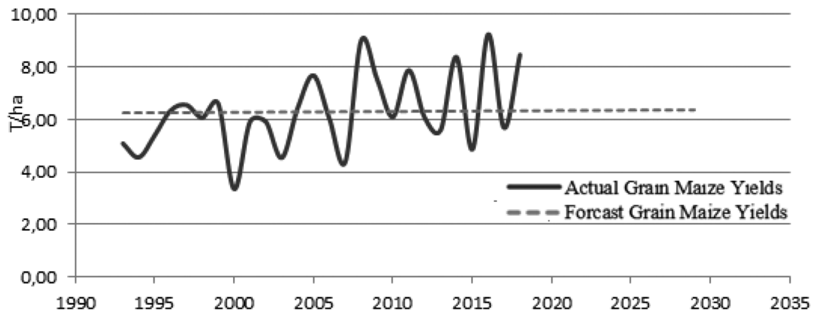

Figure 2. Actual and forecasted values of grain maize yields (T/ha) in Slovakia
Source: authors´ processing, FAOSTAT

Using Table 1 of approximate bushels of grain content in a ton of corn silage, we found out relationship from which we derived a formula to calculate grain yields of grain maize to project prices of silage maize. From the data in Table 1 the relationship was derived as it is show in Figure 3. Grain yields are estimated according to maize yields per hectare and the formula is as follows:

$$y_t = -0.0003x_t^2 + 0.0927x_t + 1.5286 \tag{10}$$

where y is grain yield in bushels per one tone of grain maize silage in year t and x is grain maize yield in bushels per one acre in year t.

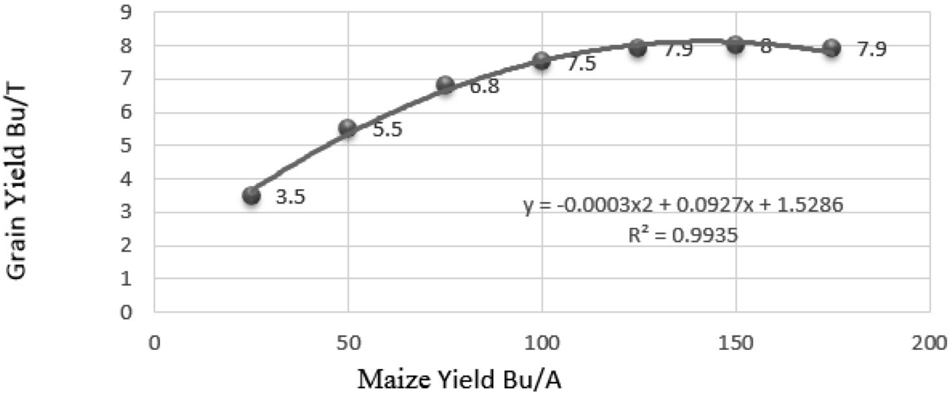

Figure 3. Relationship between grain yield of maize bushel per ton of silage and grain maize yield bushel per acre

Source: authors´ processing

c. Determining NPV of the project and estimation of payback period of biogas plants in Slovakia

To forecast economic viability of biogas sector NPV tool was used. The model of a biogas plant was constructed the way it represents as many BGPs in Slovakia as possible and contains general similarities. The scenario does not count with any other income than the one from sale of electricity and only one single input is used. Some BGPs benefit from using different types of inputs that are less costly than maize silage even though may not be as effective as the maize silage or there are also options of selling heat and fertilizers; however, these investments are costly and extremely difficult to generalize.

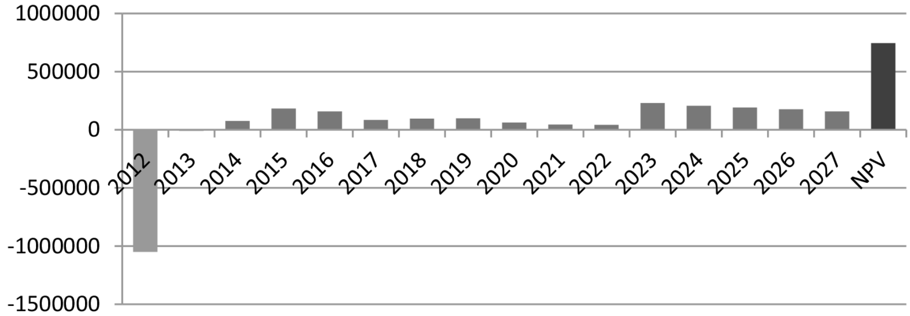

Figure 4. Discounted cash flow with final NPV value (in EUR)

Source: authors´ processing

According to Figure 4, the sum of all discounted cash flows is 745 048.01 EUR. NPV value for the project is positive which means, it is worth investing and Slovak biogas industry is economically vital. However, the result is as accurate as the silage maize price forecast, which is the most questionable element apart from technical conditions of BGPs. Even though we can easily estimate cash inflow due to guaranteed prices of electricity for 15 years, government can still interfere and decrease or increase cash inflow. An example is implementing G-component in 2014 the effect of which is as a tax levied on electricity produced from RES.

Payback period was calculated to 10 years and the initial investments including cost of capital is estimated to be regenerated by the time their maturity as the debt is to be paid by the 10th year. The BGP starts to generate profit in the 11th year of the project life with the cumulative profit in the last projected year 1 375 251.19 EUR (Figure 5).

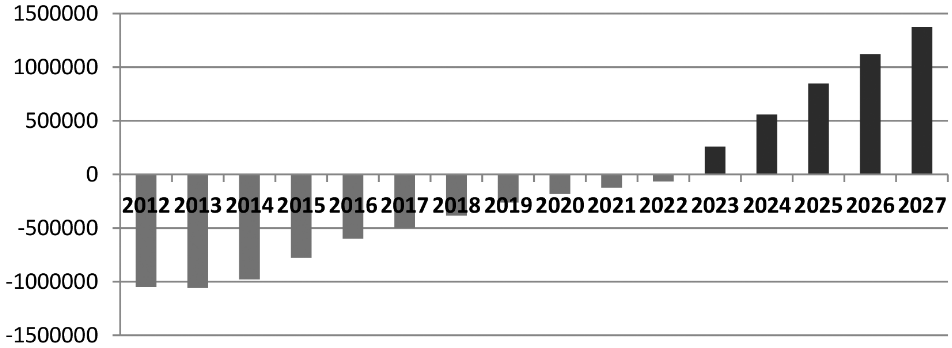

Figure 5. Cumulative cash flow (in EUR)
Source: authors´ processing

One of the most criticized week spot of the payback period tool is the fact that it does not take into account time value of money. To overcome this drawback, payback period was calculated also on the basis of discounted cash flow. The result is very similar to the previous one and it estimates 10 years for the investments to be recovered and since 11th year it starts to generate profit as it is shown in Figure 6. The cumulative profit generated in the 15th year in today`s value of money is 745 049.01 EUR.

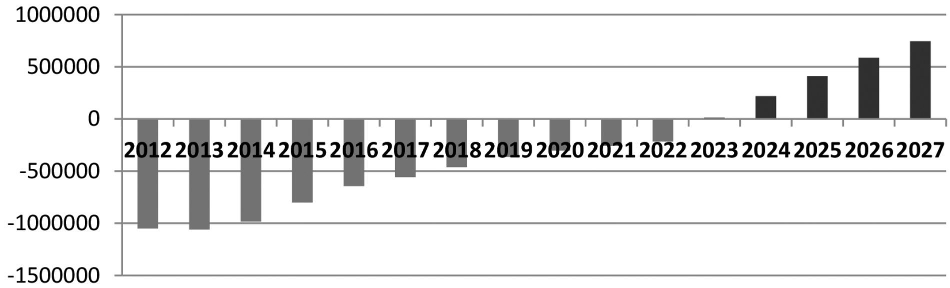

Figure 6. Discounted cumulative cash flow (in EUR)
Source: authors´ processing

3.2. The ceiling price of main input for AD – maize silage

Using the calculation to determine ceiling price of input for AD we discovered that if the one ton of maize silage costs 38.913 EUR in selected period, the model biogas plant generates zero profit. If the price is less, the plant becomes profitable, the lower the price is, the more profitable the plant is. On the other hand, any price above 38.913 EUR/T makes whole project unprofitable. According to these findings the average price of maize silage during lifetime of BGPs needs to be lower than calculated ceiling price to keep the sector profitable. Risk of increasing maize silage price endangers majority of biogas plants not only in Slovakia but also in whole Europe.

The finding is confirmed by reports from year 2013 when the price of maize silage went up to 40 EUR/T and biogas plants were generating loss as some of them admitted so. However, they were making loss, the price was not too high so they kept on production electricity to lower the loss. It can be concluded that the economic viability of biogas sector in Slovakia highly depends not only on subsidies but also on the price of maize silage which recorded significant variations over the past years. The Figure 7 shows how profitable are most of the biogas plants in Slovakia at any given price of the input – maize silage. When the revenues and other than input costs are fixed, we can estimate economic condition of biogas sector and its financial benefits for farms or firms according to price development of the maize silage.

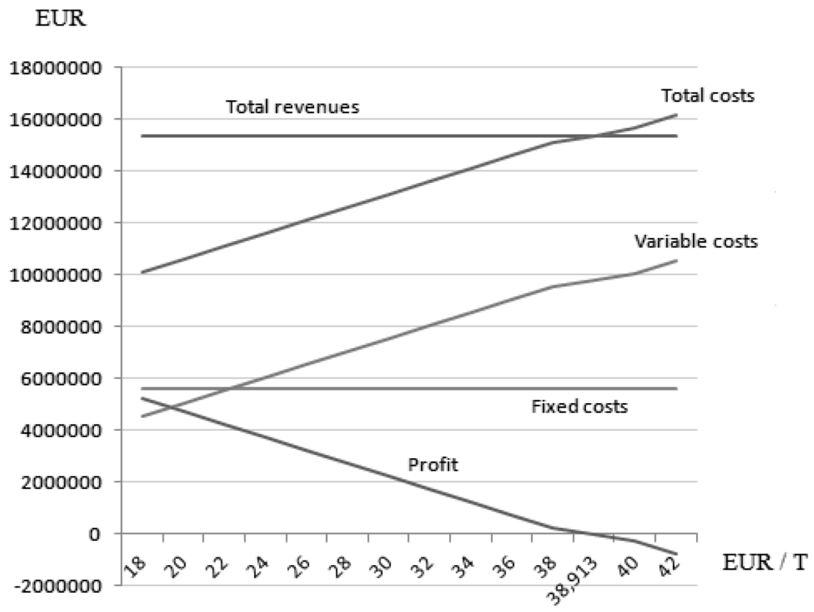

Figure 7. Profitability of BGPs in Slovakia at different prices of maize silage

Source: authors´ processing

4. CONCLUSION

The economic viability of the sector and its benefits for investors were examined using simplified model of a biogas plant scenario as a representing sample. BGP is not only an electric power source, but most importantly, it is supposed to be a stable source of income for farmers designed to help financially as their core business is extremely dependent on weather conditions and therefore very risky. Economically vital biogas sector in Slovakia is thus critical for the investors – farmers.

According to literature and biogas sector development analysis, the biogas plant model was constructed to match the majority of Slovak BGPs to have a representative sample of the biogas sector in Slovakia - BGP lunched in 2013 with legislation support from the very same year applying fixed subsidies for the next 15 years, with however later changes in legislation (G-component) included. Scale of the plant is 1 MW electric capacity, life time is 15 years and input material is silage maize bought for market prices. The prices were estimated on the basis of grain maize annual prices and its grain content in a ton of corn silage outlook. Calculation based on silage maize forecast predicts positive net present value. More accurately the investment since 2013 of about 3.5 million EUR with additional operation costs is supposed to be worth 745 049.01 EUR in 15 years. The payback period of 10 years is estimated according to cumulated cash flow and also cumulated discounted cash flow.

The analysis indicates economic viability of the sector, which is however, based on the accuracy of the silage maize price outlook. Such a long-term price prediction tends to be unreliable due to the too many random factors effecting the price development. The critical price of silage maize is calculated at the level of 38.92 EUR per ton. Former subsidy system was established when price of one silage ton was about 26 EUR per ton, while in 2013 the price went up to 40 EUR per ton and BGP were generating loss. In the case that the average price of silage maize is over 38.92 over the next 12 years, users of average Slovak BGP and overall Slovak biogas sector will be unprofitable, burden for farmer and the whole concept unsuccessful, waste of money and resources. In that case it will be a question if to let farmers to deal with unfavourable market conditions alone or more subsidize the sector. Moreover, it is also necessary to look for suitable substitutes for standardly used corn silage.

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REFERENCES

Anderson, R. G., Hoffman, D. L., & Rasche, R. H. (2002). A vector error – correction forecasting model of the US economy. *Journal of Macroeconomics*, *24* (4), 569 –598. https://doi.org/10.1016/S0164-0704(02)00067-8

Baxter (2014). Biogas integration into future energy supplies. In G. M. Gübitz (Author), *Conference proceedings for the international conference: BiogasScience 2014.* Vienna, Austria: University of Natural Resources and Life Sciences.

Braun, R., Weiland, P., & Wellinger, A. (2015). *Biogas from Energy Crop Digestion.* Retrieved from: http://www.iea-biogas.net/files/daten-redaktion/download/energycrop_def_Low_Res.pdf

Dollhofer, V. (2014). Pretreatment with anaerobic fungi, a solution to improve digestion of recalcitrant substrates? In G. M. Gübitz (Author), *Conference proceedings for the international conference: BiogasScience 2014.* Vienna, Austria: University of Natural Resources and Life Sciences.

EnergiePortal (2017). *Biogas plants in SR (Bioplynové stanice v SR).* Retrieved from: https://www.energie-portal.sk/Dokument/bioplynove-stanice-v-sr-100191.aspx

Engler R. J., Jordan, E. J., McFarland, M. J., Lacewell, R. D. (2013). Economics and environmental impact of biogas production as a manure management strategy. 109-114. Retrieved from: <https://www.agmrc.org/media/cms/Engler2_F05E9EA9371B6.pdf>

European Biomass Association (2013). *A Biogas Road Map for Europe.* Retrieved from:< http://www.aebiom.org/IMG/pdf/Brochure_BiogasRoadmap_WEB.pdf>

Food and Agriculture Organization of the United Nations (FAOSTAT). *Crops.* [statistics]. Retrieved from: http://www.fao.org/faostat/en/#data/QC

Gebrezgabher, S. A., Meuwissen, M. P. M., Prins, B. A. M., & Oude Lansing, A. G. J. M. (2010). Economic analysis of anaerobic digestion - A case of Green power biogas plant in The Netherlands. *NJAS – Wageningen Journal of Life Science,* 57, 109-115. https://doi.org/10.1016/j.njas.2009.07.006

Gangopadhyay, K., Jangir, A., & Sensarma, R. (2016). Forecasting the price of gold: An error correction approach. *IIMB Management Review, 20* (1), 6 - 12. https://doi.org/10.1016/j.iimb.2015.11.001

Holm-Nielsen, J. B., Al Seadi, T., & Oleskowicz-Popiel, P. (2009). The future of anaerobic digestion and biogas utilization. *Biosource Technology*, *100* (22), 5478-5484. https://doi.org/10.1016/j.biortech.2008.12.046

Lippert, M. (n.d.). *Calculating Grain Yield Utilizing a Corn Silage Forage Test.*
Retrieved from < https://fyi.uwex.edu/forage/files/2016/10/GrainYieldfromCornSilageII.pdf>

Mészáros, A., & Jašňák, P. (2014). Economic efficiency of the biogas plant (Ekonomická efektívnosť bioplynovej stanice). *Elektroenergetika, 7* (2), 9-14.

Patinvoh, R. J., Osadolor, O. A., Horváth, I. S., & Taherzadeh, M. J. (2017). Cost effective dry anaerobic digestion in textile bioreactors: Experimental and economic evaluation. *Bioresource Technology*, *245,* 549-559. https://doi.org/10.1016/j.biortech.2017.08.081

Pepich, Š. et al. (2010). *Usage of agricultural biomass for energy purposes and its impact on sustainable development (Využitie poľnohospodárskej biomasy na energetické účely a jej vplyv na trvalo udržateľný rozvoj).*
Retrieved from: <http://www.tsup.sk/files/vyuzitie_poln.biomasy_na_energet.ucely.pdf>

Santadkha, T., & Skolpap, W. (2017). Economic Comparative Evaluation of Combination of Activated Carbon Generation and Spent Activated Carbon Regeneration Plants. *Journal of Engineering Science and Technology, 12* (12), 3329-3343.

Weil, R.M., & Maher, M.W. (2005). *Handbook of Cost Management* (2nd ed.). Hoboken, New Jersey: JohnWiley & Sons, Inc.

Wellinger, A. (2014). Challenges and opportunities. In G. M. Gübitz (Author), *Conference proceedings for the international conference: BiogasScience 2014.* Vienna, Austria: University of Natural Resources and Life Sciences.