# TECHNICAL-ECONOMIC EVALUATION OF CORN SILAGE AND MANURE FOR ELECTRICITY AND HEAT PRODUCTION IN SLOVAK REPUBLIC

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**Abstract:** *This article is focused on technical-economic evaluation of the efficiency of corn silage in comparison with manure in case of combined production of electricity and heat. Mentioned energetical sources are used for production of biogas by fermentation in biogas plants, which include equipment for cogeneration. We analysed resources' efficiency of installations with installed capacity of 1MW. We found the the use of manure with deterministically defined value, NPV 2 508 303 EUR and IRR 26.35% is more effective. NPV for corn silage was 1 690 562 EUR and IRR 21.37%. Price of electricity, use of electricity and initial investment in both projects have the greatest impact on the change of criterion. Taking into account the risk from Monte Carlo simulation, we found, that with any risk aversion, the NPV of the monitored projects will never be negative. Functions of density and distribution confirmed the ranking of energy resources' efficiency obtained using NPV and IRR criteria. It can be stated that both investment plans are very perspective.*

**Keywords:** *Efficiency, Biomass, Cogeneration.*

## 1. INTRODUCTION

No mature civilization can imagine everyday life without electricity or without heat during winter period. As the population is still growing and technology evolves, the question of sufficient energy reserves is very important. Fossil fuels are often very criticized for their environmental impact and the urgency of replacing them by renewable sources is increasing. The question arises: to what extent are we able to replace conventional resources by alternative ones, and if it is economically efficient. The usage of alternative sources often requires new approaches in technology, which may be more efficient than conventional sources, but less affordable. That is why we decided to focus our attention on the research oriented on efficiency of using two alternative energy sources: corn silage and pig manure. These energy sources are used for biogas production by fermentation in biogas plants, which include cogeneration plants. They are used for combined production of electric and heat energy. From a practical point of view and assuring sufficient quantities, these sources are suitable for installations with installed capacity approximately up to 1 MW.

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## 2. THEORETICAL BACKGROUND

There is no precise guidance on assessing investment projects. When investing, it is extremely important to choose an evaluation methodology already in the project preparation phase, and if we want to compare them, it is important to keep the same methodology for all of them. Although the existing methods considerably vary in their implementation, they all share a common principle – they are based on the budget calculation of the project's economic return, which is defined as a series of discounted cash flows (Chiesa and Frattini, 2009). The value of innovation is measured in terms of its contribution to creating economic value from the required investments. This technique offers many variations (Koller, Goedhart, Wessels, 2010). Kroi and Oclon (2018) addressed the question of the profitability of energy production for combined heat and power installations. They developed a mathematical model for this analysis. According to the authors, mathematical modeling has proved to be a reliable tool for evaluating the efficiency and profitability of a cogeneration unit.

The criterion of Net Present Value (NPV) is considered by Dallimer et al. (2018) as the generally acceptable criterion used in the assessment of the technical and economic feasibility of installing geothermal drilling systems to exploit geothermal energy production in Ukraine. They designed the expected performance and profitability for different depths and thermal water flows using analytical heat transfer methods combined with the current net value. The technical-economic analysis of biofuel production was presented by Ingle, Chandel and da Silva (2020). They used discounted cash flows to estimate NPV. They allowed organizations to decide which projects to continue and how to optimize them to maximize profits. Hazen (2003) defined Internal Rate of Return (IRR) as a method which can be use for any project selection decision. This method requires the definition of the cash flow investment balance and a discount rate analysis. The method is in accordance with the present value.

There are many sources of risk that a decision-maker must take into account before making a decision to invest. Therefore, it is important that sources of risk are available. Only then, it is possible to carry out the necessary identification, analysis and response. The source of risk is any factor that may affect the investment project or performance of a business. The risk occurs when this effect is both uncertain and significant in its impact on the project or on the performance of the company (Merna and Al-Thani, 2007). In order to identify risk factors, the sensitive analysis can be used. The sensitivity analysis can be defined as follows: It is an examination of how uncertainty in model output (numerical or otherwise) can be divided into different sources of uncertainty in model inputs (Saltelli et al., 2004). The impact of identified risk factors should be subsequently analyzed by using a simulation method which analyzes several possible scenarios.

The Monte Carlo method is widely applicable. It is used to determine the approximate solution of probabilistic and deterministic problems by means of repeated random experiments. The use of method is based on establishing a probabilistic problem that has the same solution as the original problem. Stochastic-technical-economic analysis was performed by Frank et al. (2018) in the production of willow biomass. The model was based on input price parameters for production and willow yield. With Oracle Crystal Ball program, they earned 24-year net present value under price and revenue uncertainty. They found the interval at which it moves and NPV at 95% confidence level. The main contribution of their paper is determining the probability of acquiring NPV values. With ASPEN Plus® V8.2, Haigh et. al. (2018) proposed six conceptual scenarios of the producing biofuel process from biomass by fermentation, using the process performance data. The most efficient scenario was also the best performing scenario, with the best values of NPV and IRR. The technical-economic efficiency of gasification of biomass from Spartina argentinensis in Argentina for combined energy purposes was evaluated by Emiliano (2017). The investment plan was subjected to a sensitive analysis, based on which the lower and upper limits of NPV were expressed. He pointed out on the importance of the impact of natural gas prices on economic results. According to research, energy efficiency and selling price of electricity have been identified as the most important factors affecting NPV.

## 3. METHODS

The basis of the evaluation of the technical-economic effectiveness of investment projects is the correct construction of a multi-period balance model, which consists of technological and economic input data. Subsequently, we evaluated efficiency using two criteria: the net present value (NPV) and the internal rate of return (IRR). NPV is defined as the sum of the current annual net income values obtained during the project implementation period. A project with a positive NPV is acceptable. The project with negative NPV is rejected (Roštárová, 2016). IRR is the rate at which the net present value of the project is 0. The evaluation of project acceptance is based on the relationship between IRR and discount rate (Hartman and Schafrick, 2010). The project which has higher IRR than discount rate is accepted.

For quantification of IRR, we used hypothesis analysis available in Microsoft Excel software. For identification of the risk factors, we used sensitivity analysis, which examines the effect of changing one input factor on changing the target criterion (Hanafizadeh, 2004). We examined the effect of a 10% factor change. If it causes a change of more than 10%, it is a risk factor. Deterministic assessment (NPV and IRR) was strengthened by stochastic analysis, taking into account the risk in decision making. We simulated 1000 scenarios for each variant using the Monte Carlo method in the promo version of @Risk for Microsoft Excel. It provided the probabilities with which NPVs would acquire certain values as well as the possibility of a comprehensive comparison of investment projects using density and distribution functions. Data for the analysis were obtained from private companies that had a study carried out for each investment project.

## 4. DATA ANALYSIS

We evaluated two projects: a biogas plant with the main input of corn silage and the second plant with the main input of manure with an installed capacity of 1 MW with a lifetime of 15 years. In the following part, we describe the components of the multi-periodic balance model. The investment for a corn silage project is 4 046 428 EUR and for manure 4 396 000 EUR. The layout of the technological and architectural part is 70% and 30%. Our analysis is based on one bank loan at a discount rate of 4.7%. The repayment period is 6 years with a 2-year period of grace. Acquired assets were allocated into depreciation groups. The technological part was included in the 4th group with 12 years of repayment and the construction into the 5th group with 20 years of repayment. 1 MW of electricity per hour and 0.86 MW of heat energy is produced in case of manure. In case of corn silage the ratio is 1 : 1. Both heat and electricity are generated 8040 hours per year, with 70% of its own electricity consumption and 1,582 MW for corn silage and 1,360 MW for manure. The price of heat is set at 59.60 EUR per MW and the price of electricity is set at 134.08 EUR in order to favor the production of electricity from waste biomass by fermentation and biogas production.

In addition to energy, digestate is produced as well, which is a high-quality organic fertilizer. The use of corn silage produces 19 077 t per year and 50 000 t for manure, which can be sold at price agreed with the customer. We considered a unit price of 1 EUR. We had foreseen an external maintenance cost of 78 500 EUR for energy production facilities and the same amount for external maintenance of other facilities. For corn silage we considered one employee (part-time) at cost of 7 700 EUR and for manure we considered two employees at cost of 24 500 EUR. Equipment insurance costs were set at 16 800 EUR per year. Other unspecified material needed for corn silage requires annual cost of 12 000 EUR. For cogeneration of corn silage we need 17 150 t of corn silage at a price of 24 EUR, 6 500 t of sludge at unit price of 1 EUR and 200m$^3$ of water at unit price of 0.50 EUR. In case of second project, the material cost include manure from 30 000 t of pigs per year at price of 0,10 EUR, 10 000 t of sorghum silage at price of 12 EUR, 1 700 t of fat at price of 5 EUR and 63 100 t of oil for 0,80 EUR/t.

Both biogas plants represent perspective projects, because the cumulative cash flow calculation is positive throughout the reporting period. However, the second investment project with manure appears to be more efficient, because of higher values.

**Table 1.** Cash flow for cogeneration 1MW in EUR

| **Years** | **3** | **16** | **17** |
|---|---|---|---|
| **corn silage** | | | |
| Cash flow | 101 085 | 639 631 | 639 631 |
| **cumulative Cash flow** | 101 085 | 5 600 440 | 6 240 071 |
| discounted **Cash flow** | 80 244 | 186 702 | 172 872 |
| **manure** | | | |
| Cash flow | 225 434 | 786 226 | 786 226 |
| **cumulative Cash flow** | 225 434 | 7 362 981 | 8 149 207 |
| discounted **Cash flow** | 178 957 | 229 492 | 212 492 |

**Source:** own processing

We evaluated the efficiency of projects using the investment decision criteria. The net present value of Project 1 was 1 690 562 EUR, but for Project 2, it was higher - 2 508 303 EUR, resulting in better efficiency of the manure biogas plant. The second criterion - IRRis higher than the chosen discount rate of 8% for both projects (corn silage 21.37% and manure 26.35%), proving that both projects will yield a return higher than the return on the capital market at the given rate.

The evaluation criterion is influenced by the input parameters. Their effect was monitored using a sensitivity analysis, from which we expressed the risk factors.

We analyzed the impact of the 10% change of the risk factors on the NPV. In this case, the price of electricity, the use of electricity and the discount rate had the greatest impact on both variants. If we increased the price of electricity, NPV would fall by 35% for corn silage and by 23% for manure. NPV decreases by the same values when the electricity use is reduced. The change in the initial investment would change NPV by 17% for corn silage and by 13% for manure. The price of the main input is only a risk factor for maize silage (14%), the same applies in case of the price of heat (13%). The discount rate for corn silage will bring 12% change and for manure over 10%. Factors are referred to as risk factors. In order to take into account the risk, we performed a simulation of 1000 scenarios for each project. We used the Monte Carlo method to determine the impact of all risk factors at once on the target criterion NPV.

The manure biogas plant is the most suitable option due to the highest mean value of NPV (2 542 230 EUR). It may range from 1 648 481 EUR to 3 528 288 EUR. The mean value of NPV of corn silage is 1 735 756 EUR and may range between 667 875 EUR and 2 845 570 EUR. With a probability of 68%, NPV values will range from 2 196 508 EUR to 2 888 552 EUR for manure, and from 1 372 521 EUR to 2 098 991 EUR for corn silage. The coefficient of skewness is very close to 0, indicating normal distribution. The coefficient of kurtosis shows a more pointed distribution (manure 2.61 and corn silage 2.85) than the normal distribution of each project, and the probability of extreme values fluctuating around the mean value is reduced. The probabilities with which NPV for each variant will fall below the value assigned to that probability are shown in Table 2, which expresses the risk of reaching the assigned value.

**Table 2.** Critical values of NPV for individual variants of cogeneration 1 MW

| source | corn silage | manure |
|---|---|---|
| **5%** | 1 131 417 | 1 952 891 |
| **10%** | 1 251 779 | 2 085 947 |
| **20%** | 1 424 471 | 2 251 337 |
| **25%** | 1 495 516 | 2 304 494 |
| **30%** | 1 542 343 | 2 360 262 |
| **35%** | 1 601 743 | 2 410 743 |

**Source:** own processing

Even with probability of 5%, we can expect the NPV of the first project will not fall below 1 131 417 EUR and for the second project below 1 952 891 EUR. By analogy, if at 5% this is a given value, than with a probability of 95% the value will be higher than this one.

To compare the efficiency of biogas stations, the density functions are shown in the Figure 1.

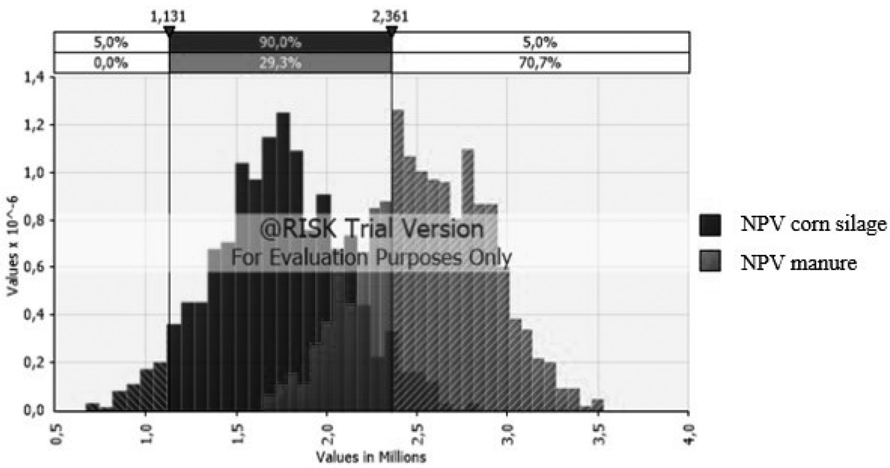


**Figure 1.** Function of density for both variants

**Source:** own processing

Based on the results of our analysis, the use of manure clearly turned out to be more efficient project, since its NPV values in the graph are much more to the right (NPV reaches a higher mean value), while both distribution functions are similarly steep, thus having a similar level of risk. In case of investment into corn silage biogas plant there is a 90% probability that NPV will be from interval 1 131 417 EUR to 2 360 513 EUR, and with the probability of 5%, the NPV will be higher than the upper limit of the interval. In case of manure, the values will be higher with 70.7% probability.

The use of manure has proved to be a more effective project. The probability of acquiring the expected NPV (corn silage 1 690 562 EUR, manure 2 508 303 EUR) by a deterministic assessment is 44.7% for corn silage and 45.6% for manure.

When analyzing 1 MW biogas stations, there is a different correlation between risk factors and NPV. There is a moderate correlation between the electricity selling price and the assessment parameter, which takes values for corn silage 0.6 and manure 0.7. The initial investment represents negative low correlation for corn silage (-0.44) and negative medium correlation for manure (-0.54). The use of electricity in conjuction with NPV has a positive low correlation of 0.45 for silage and 0.47 for manure. Among these factors, there are relatively similar correlations with the output variable for variations. With the use of manure, the price of corn silage (-0.25) or the discount rate (-0.21) have relatively low negative correlation and the heat price (0.22) have a positive correlation.

Picture 4 provides an overview of the distribution functions for the two cogeneration plants with a power output of 1 MW differing in their source of use. Distribution functions provide a comprehensive comparison of the two projects. The graph illustrates the existence of a first degree stochastic dominance. The stochastic dominance of the next stages does not occur because the distribution functions of investment project do not intersect.

The biogas plant for manure strongly dominates the corn silage plant, respectively the project two is strongly dominated by the project one. The arrangement of the distribution functions results in the ranking of effectiveness of the projects - 1st manure and 2nd corn silage.

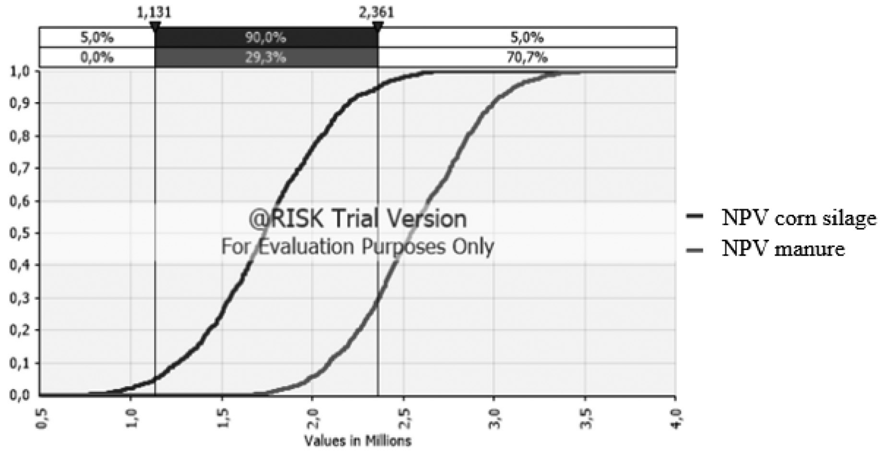


**Figure 2.** Distribution functions for both variants

**Source:** own processing

## 5. CONCLUSION

We were focused on evaluation of the efficiency of the use of corn silage and manure in combined production of electricity and heat in cogeneration plants with an installed capacity of 1MW. Both projects are very perspective, based on selected criteria. Price of electricity, its use and the initial investment are factors which have the greatest impact on NPV. Distribution functions confirmed that the NPV, at any level of willingness to take the risk, will not show negative values. In the moment of decision-making between certain investment plans, it is up to each subject, which project they will choose. The effectiveness of the project is influenced by various factors and it is only up to investor to decide based on what arguments he will choose the winning option. This may also be supported by a risk analysis and his willingness to endure a certain risk plays a role as well. Unfortunately, even nowadays the willingness to bear a certain risk can not be accurately quantified.

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