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Economic Viability of Centralized Biogas Plants: A Case Study for Croatia

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Biogas plants are an established and widely used technology in a number of European countries, but their utilization in Croatia is hampered by the state of its agriculture sector. Small farms, often with less than 15 heads of cattle, are common and they are not capable of independently running a biogas plant. For that reason, centralized biogas plants could present a viable option for smaller farms like the ones mostly present in Croatia.
The utilization of biogas can have a number of positive effects on the day to day operations of a farm. Biogas plants can reduce the carbon footprint of a farm, help with manure management and additionally, they can provide a source of income to the owner. Since they present a sizeable investment, it is crucial to properly evaluate the feasibility of such investments.
The goal of this work is to evaluate and present the impact that the size of the plant, content of manure in the substrate, the transport distance and efficiency have on the economic viability of centralized biogas plants. A case study for Croatia has been created for this purpose. The results will demonstrate the economic viability of larger biogas plants and the high impact transport has on it.

1. Introduction

Biogas utilization is an important approach to the problem of bio waste management from households, industry and agriculture. This is especially attractive for the handling of animal manure on farms. Not only can the implementation of biogas plants reduce the greenhouse gas emissions from a farm through the burning of the produced methane, it also produces electricity, heat and digestate, a high quality biological fertilizer, (Abubaker, et al., 2012) which can all generate extra profit for its owner. It is estimated that 590 - 800 Mt of methane are released into the atmosphere by natural degradation of biological material under anaerobic conditions (Bond and Templeton, 2011).
The most important issues facing the European energy sector are security of supply and greenhouse gas (GHG) emissions (Ćosić, et al., 2011). The need for the reduction of GHG emissions is also true for other sectors such as industry (Mikulčić, et al., 2013), households (Pukšec, et al., 2013a), transport (Pukšec, et al., 2013b) and agriculture (Robaina-Alves and Moutinho, 2014). Biogas plants can help both with the reduction of GHG emissions of the agriculture sector as well as increase the local electricity production from renewable sources.
Biogas plants are an established and widespread technology in Europe. In Germany for example, there are currently over 7500 biogas plants in operation (Lorenz, et al., 2013). In 2008 there were approximately 200 biogas plants in operation in Italy (Zubaryeva, et al., 2012), nowadays there are over 520 (Bacenett, et al., 2013). In Denmark there were 20 centralized and more than 35 farm scale biogas plants in operation in 2007 (Ravena and Gregersen, 2007). Biogas is also often upgraded (Gamba and Pellegrini, 2013) to biomethane which can be injected into the national gas grid or used as vehicle fuel (Niesner, et al., 2013). There are currently only 14 biogas plants in operation in Croatia (HROTE, n.d.) even though there is a significant potential for their use (Pukšec and Duić, 2011).
A real issue for the utilization of biogas in Croatia is the small size of the average farm. According to the census of agriculture from 2003 (CBS, 2003), the average family farm consisted of 2 ha of land, and only

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21 % of the agricultural land in private ownership is cultivated. Businesses own an average of 159.2 ha. There are 44,560 dairy producers in Croatia according to the same source, 96 % of which own less than 15 cattle, roughly one third of business own less than 20 cattle while the rest have more and only 86 of them own more than 100. In 2003 the average number of pigs was 8 for family farms and 464 for business. 90 % of the production is in the hands of 200,000 small farms, 170,000 of which own less than 10 pigs. Because of this, centralized plants should be considered.
The impact of the size of the biogas plant, the amount of animal manure being used as the substrate and the transport distance and efficiency on the internal rate of return (IRR) have been analyzed for the purpose of this work. Multiple scenarios have been created and analyzed and the results have been compared.

2. Methodology

In order to analyze and compare the effect of different parameters on the economic viability of centralized biogas plants, an MS Excel based model has been developed. The model is used to calculate the IRR of the different scenarios used for the comparison. Six base scenarios have been created for this purpose. The six scenarios are biogas plants with an installed power of 250 kWel, 500 kWel and 1000 kWel using either cattle or pig manure as a substrate. After the initial scenario has been created, the different parameters used in the model have been modified in order to quantify their impact on the economic viability of the plant. The basic scenario is one with a 500 kW biogas plant on a dairy farm with 50 % of the substrate being animal manure, a transport distance of 50 km and an average transport efficiency. The parameters are the amount of manure used as a substrate (20 %, 50 % or 80 %), transport distance (10 km, 20 km, 40 km, 60 km or 80 km) and the efficiency of the transportation method (average efficiency, less efficient or more efficient). The average fuel efficiency can be calculated using Eq(1).

$$\mathrm{ATFE}=\frac{\mathrm{TECT}\times\mathrm{SFT}}{\mathrm{TFT}\times\mathrm{Hd_d}} \tag{1}$$

ATFE – average fuel efficiency [L/tkm]
TECT – total energy consumption of the road transport [kWh/y]
SFT – share of freight transport in total road transport [%]
TFT – total freight transport achieved [tkm/y]
$\mathrm{Hd_d}$ – lower heating value of diesel [kWh/L]

The investment cost for the three different biogas plants were taken from (JRC, 2011)and (DEA, 2010). An electric efficiency of 40 % and a thermal efficiency of 38 % as well as an annual operation of 7,884 hours (availability of 90 %) have been presumed for all three plants.
The specific energy derived from the different substrates used in the analysis has been taken from (KTBL, n.d.). The energy derived from cow manure equals 167 kWh/t, 121 kWh/t from pig manure and 1120 kWh/t from maize silage. The price of maize silage of 32 €/t was used in this paper.
The IRR is presented in Eq(2). It is equal to the discount rate at which the net present value of the project equals 0 for the observed period of time. It has been calculated using Excels function IRR.

$$\mathrm{NPV}=\sum_{n=0}^{N}\frac{C_n}{(1+\mathrm{IRR})^2} \tag{2}$$

NPV – net present value of the investment [€]
n – current period
N – total number of observed periods
C_n – cash flow in period n [€]
IRR – internal rate of return [%]

2.1 Case study: Croatia

The transport efficiency for Croatia was calculated using the data obtained from (CBS, 2011), (EIHP, 2010) and (EIHP, n.d.). The average efficiency of freight transportation using trucks and light transport vehicles has been calculated to be approximately 0.09 L/tkm. A less efficient alternative of 0.11 L/tkm and a more efficient alternative of 0.07 L/tkm have also been compared. The price of fuel has been taken from (INA, n.d.).
The feed in tariff for biogas plants in Croatia depends on the installed electrical power of the plant. The tariff for a plant with a power up to 300 kWel is 1.42 kn/kWh, which is 0.19 €/kWh, and the tariff for biogas plants up to 1000 kWel is 1.2 kn/kWh or 0.16 €/kWh (HROTE, n.d.). The feed in tariff is valid for a period of

14 years (HIDRA, n.d.) and the operator of the distribution system is obliged to take in all of the electricity produced from renewable sources or cogeneration.

A loan with an interest rate of 5 %, a payback period of 10 years and 30 % equity has been used in this paper. An income tax rate of 20 % has been used. An escalation factor of 2 % annually has been used for all of the created scenarios.

3. Results

Figure 1 presents the influence that the share of manure in the substrate has on the IRR of the proposed investment. The percentages represent the share of energy received from the manure in the total gross energy needed by the plant, not the mass or volume. It can be seen that the higher shares of animal manure result in a better IRR. This is naturally expected since it reduces the need for purchased maize silage. Better results are achieved for dairy farms than for pig farms. If the installed electrical power is observed, the best results are achieved for a 1000 kW plant, followed by the 250 kW plant and finally the 500 kW plant. The 250 kW plant is economically more feasible because of the higher feed in tariff for biogas plants with an installed electrical power lower than or equal to 300 kW. The IRR varies from 8.22 % to 19.5 %. In the case of the 1000 kW plant on a dairy farm, the IRR varies from 13.64 % for 20 % of manure to 19.5 % for 80 % manure.

Figure 2 presents the influence that the transport distance has on the IRR. The transport distance has a very strong influence on the economic viability as the figure shows. The IRR varies from -0.99 % to 22.04 %. In the case of the 1000 kW plant on a dairy farm the IRR varies from 22.04 % for a transport distance of 10 km to 9.72 % for 80 km. The presented plant would still be economical with a transport distance of 60 km. This distance is reduced for other options, 20 km for a 500 kW and 40 km for a 250 kW plants.

The influence of the transport efficiency is presented in Figure 3. As it is expected, a lower efficiency reduces the IRR and a higher efficiency increases it. The IRR varies from 7.05 % to 18.79 %. In the case of the 1000 kW plant on a dairy farm the IRR varies from 15.36 % for a lower efficiency to 18.79 % for higher.

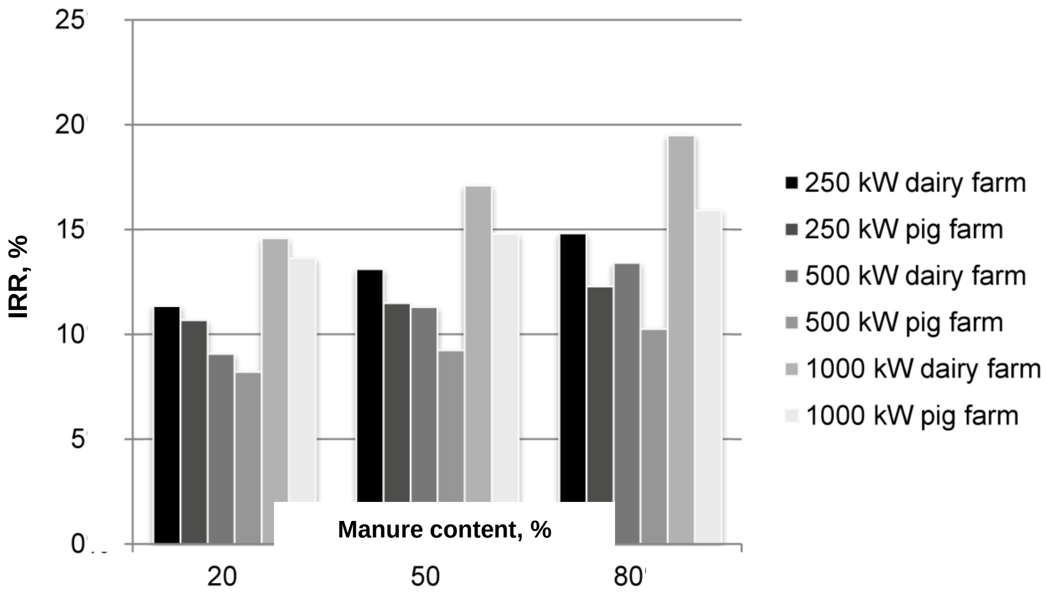

Figure 1: Influence of animal manure in substrate on the IRR

The results of the conducted sensitivity analysis have been presented in Figure 4. Four parameter have been varied from -20 % to +20 % in order to analyze their impact on the economic feasibility of the project. The four parameters are the investment cost, price of electricity, cost of substrate and the cost of fuel. The analysis has been performed for the case of a 500 kW plant on a dairy farm with 50 % manure as substrate, 40 km transport distance and an average transport efficiency.

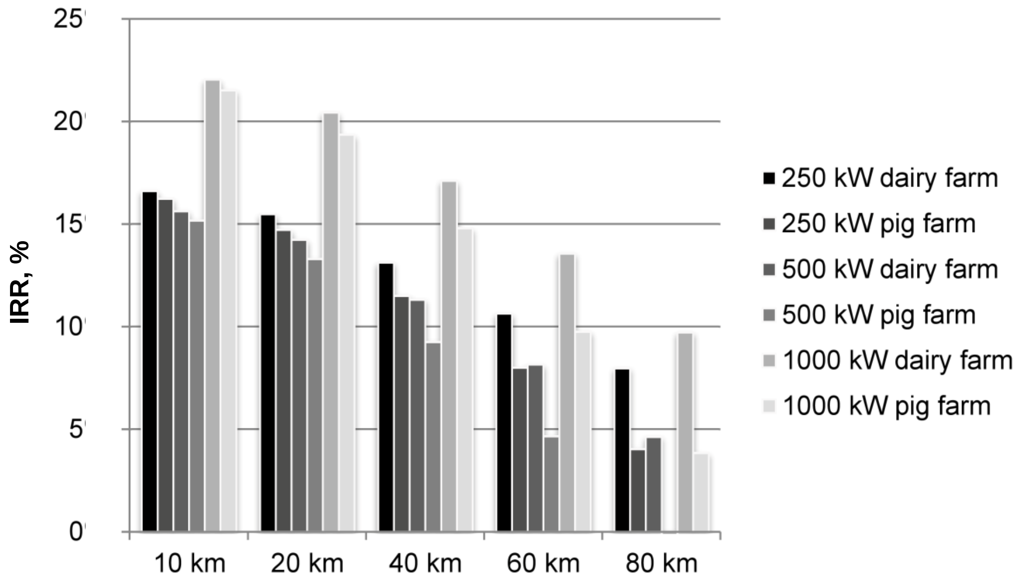

Figure 2: Influence of the transport distance on the IRR

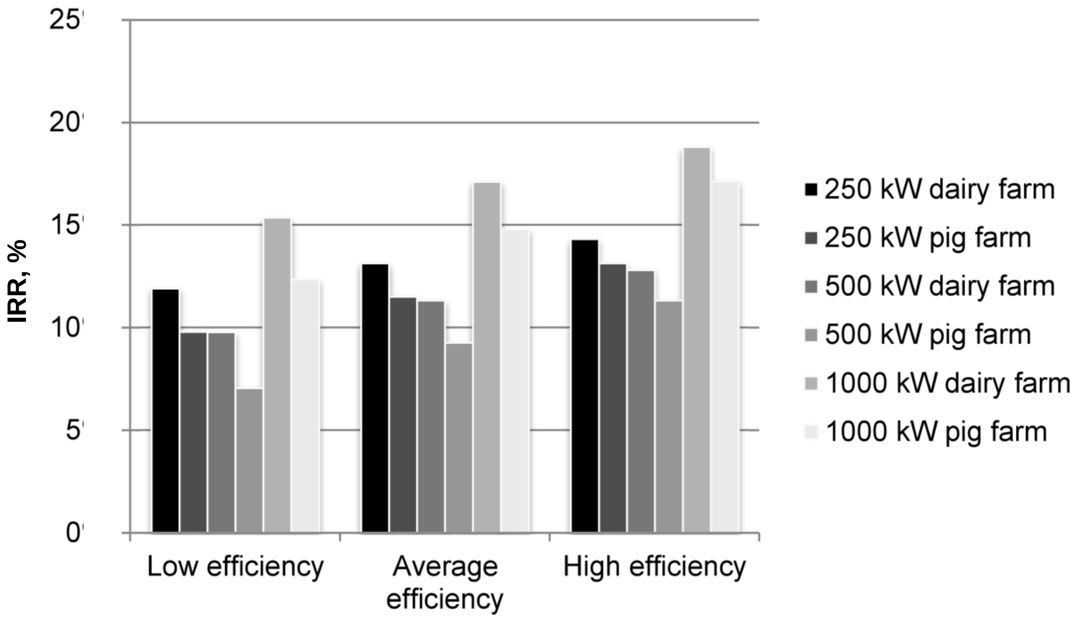

Figure 3: Influence of the transport efficiency on the IRR

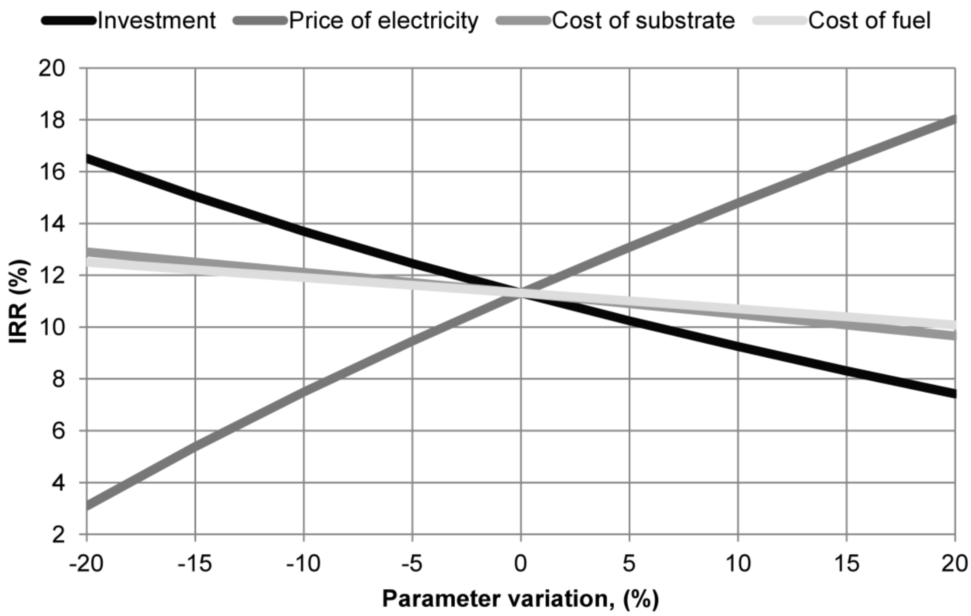

Figure 4: Sensitivity study

Table 1 presents the results of the sensitivity study in greater detail. Each row presents the IRR for one parameter (investment, price of electricity and so on) varied in a range of -20 % to +20 %, as in Figure 4.
It can be seen that the price of electricity has the greatest impact on the economic feasibility of the project with the IRR varying from 3.10 % to 18.03 %. The investment cost has the second highest impact on the IRR, varying it from 7.42 % to 16.51 %.

Table 1: Sensitivity study

	-20.0 %	-15.0 %	-10.0 %	-5.0 %	0.0 %	5.0 %	10.0 %	15.0 %	20.0 %
Investment	16.5 %	15.0 %	13.7 %	12.5 %	11.3 %	10.2 %	9.3 %	8.3 %	7.4 %
Price of electricity	3.1 %	5.4 %	7.5 %	9.5 %	11.3 %	13.1 %	14.8 %	16.4 %	18.0 %
Cost of substrate	12.9 %	12.5 %	12.1 %	11.7 %	11.3 %	10.9 %	10.5 %	10.1 %	9.7 %
Cost of fuel	12.5 %	12.2 %	11.9 %	11.6 %	11.3 %	11.0 %	10.7 %	10.4 %	10.1 %

4. Conclusion

The analysis performed for the purpose of this paper has shown that a centralized biogas plant in Croatia can very well be economically viable. The internal rate of return can vary greatly depending on the size of the plant, the substrate being used, the transportation distance and transportation efficiency.
Larger centralized biogas plants that use mostly animal manure as a substrate as opposed to bought maize silage and have a shorter transportation distance can be economically very feasible with an IRR as high as 15 % to 20 %. A transportation distance greater than 60 km has proven to be economically not feasible for any of the observed scenarios. In conclusion, a greater focus should be given to larger centralized biogas plants as opposed to smaller, farm scale units. Care should be taken to ensure a large enough local supply of animal manure, or other waste, not just from an economical but also an ecological point of view. The focus of this work has been the economic feasibility of biogas plant operation and future research of this topic will also include a detailed analysis of CO_2 emissions.
According to the performed sensitivity study, the price of electricity and the investment cost have the highest influence on the economic feasibility of a centralized biogas plant in Croatia. A reduction of the investment cost by 20 % can increase the IRR from 11.31 % to 16.51 % while an increase of the investment by 20 % can reduce it to 7.42 % in the observed case. The reduction of the price of electricity on the other hand can decrease the IRR to 3.1 % and an increase of the price by 20 % can increase it to 18.03 %.

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