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THE POSSIBILITY APPLICATION OF BIOGAS PLANT

MOGUĆNOST PRIMENE BIOGASNIH POSTROJENJA

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ABSTRACT

The main goal of this paper is to point out the possibilities of investment into biogas facilities, i.e. the economic justification of their construction. In this paper, a parametric model of a biogas facility is presented, which was modelled by means of the Catia V5 software while using cow manure as a substrate. An analysis was performed at facilities designed for 100-5000 livestock units. The presented data indicate the investments in biogas facilities, quantities of produced thermal and electric energy, and achieved revenues from electric energy sales according to feed-in tariffs . The repayment period for a different number of working days of the facility during a year is also shown. The results indicate that constructing biogas facilities for the farms with lower capacities is not profitable, but for the farms with higher capacities (over 2000 livestock units) the repayment period is only 4 years.

Keywords: *biogas plant, co-generation, animal manure, anerobic digestion.*

REZIME

Osnovni cilj ovog rada je da ukaže na mogućnost ulaganja u biogasna postrojenja, odnosno ekonomsku opravdanost njihove izgradnje. U okviru ovog rada predstavljen je parametarski model jednog biogasnog postrojenja izmodelovan pomoću softvera Catia V5, kao supstrat korišćen je goveđi stajnjak. Izvršena je analiza za postrojenja veličine od 100 do 5000 stočnih jedinica. Prikazani su podaci o investicionim ulaganjima u biogasna postrojenja, količini proizvedene toplotne i električne energije kao i ostvareni prihod od prodaje električne energije prema povlašćenojtarifi. Takođe prikazan je i period otplate za različiti broj radnih dana postrojenja u toku godine. Rezultati su ukazali da je neisplativo praviti biogasna postrojenja za farme sa manjim kapacitetom, ali i da za kapacitete preko 2000 grla period otplate se može očekivati već posle 4 godine.

Ključne reči:*biogasno postrojenje, kogeneracija, životinjski stajnjak, anaerobna digestija.*

INTRODUCTION

A continuing energy crisis has reawakened the interest in anaerobic fermentation of animal and vegetable waste resulting in methane production. To date, 80% of the world's energy use still originates from combusting fossil fuels (Goldemberg and Johansson, 2004). Yet the reserves are limited, and their burning substantially increases greenhouse gas (GHG) concentrations. Biofuels are suitable to substitute fossil fuels as energy sources. Therefore, a substantial contribution can be achieved in the effort to mitigate the additional greenhouse effect. In 2020, renewable resources shall cover 20% of the primary energy demand within the European Union. In the second half of the century this contribution has to reach 50% in order to prevent an unpredictable extent of climate change (IPPC, 2001). Among renewable resources, anaerobic digestion and utilisation of the biogas produced will play a considerable role as biogas is a universal energy resource comparable with natural gas. Of the many bioenergy related processes being developed, those processes involving microorganisms are especially promising, as they have the potential to produce renewable energy on a large scale, without disrupting strongly the environment or human activities (Rittmann, 2008).

Several large demonstration plants are functioning well and many small units are in daily use (Malcolm and Chris, 1979). The total amount produced is small but of great significance locally. Using manures from animal husbandry for anaerobic digestion has a very positive ecological effect. The life cycle assessment delivers an avoidance of greenhouse gas (GHG) emissions of approx. 600 g $CO2eq \cdot kWh^{-1}$ of electricity and heat generated from biogas based on manure (Jungmeier et al., 1999). Zoranovic et al. (2008) investigated the anaerobic treatment in a digester of a biogas plant. The digester capacity was from 300 to 1500 m^3. Sklenka (2000), using a lab-scale model, conducted the study on the problem of heating digester (the capacity of $5m^3$).

The main objective of this study is to investigate the applicability of biogas plants. For this purpose, the parametric model of biogas plant with a capacity of 100 to 5000 livestock was made. For the purpose of assessing the profitability of biogas plants, the costs of plant construction and the revenues from sold electric energy are taken into account.

Biogas plants and components

The appearance of facilities strongly depends on the type and quantities of raw materials used for biogas production. In this paper, a parametric model of a biogas facility is presented, designed with the Catia V5 software package, Figure 1. Cow manure was used as a raw material; the model is developed for the facilities of small/medium capacity for 100-5000 livestock units. The facility consists of a continuous digester, fresh manure warehouse, digestate warehouse with membrane for biogas collecting, scrubbers for biogas purification, storage tank for biogas, cogeneration plant, combustion torches, and supporting infrastructure.

Fig.1. Biogas plant

Storage of raw material and digestate

Raw materials are being stored primarily in order to compensate seasonal fluctuations in raw material supply. Storage can be used for mixing different kinds of raw materials (co-substrates) for continuous use in digester. The type of storage capacity depends on the raw material. Capacity sizing of a warehouse is based on quantities intended for storing, delivery intervals and daily intake into the digester.

Volume of fresh manure storage V_{ss}(Figure 2) is defined by the following equation:

$$V_{ss} = 90\ Q_{ts} \tag{1}$$

where: Q_{ts} - total daily volumetric flow of slurry

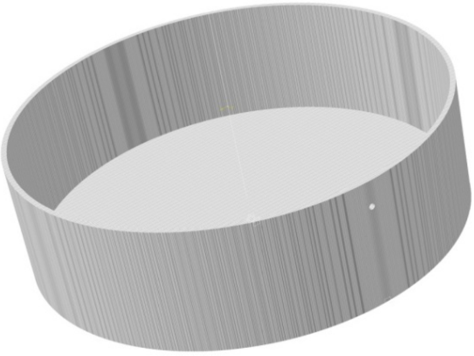

Fig. 2. Storage of fresh manure

At intervals, fermented substrate is pumped out from the digester as a digestate and through a pipeline transported to warehouses for digestate storage, figure 3. Warehouses are situated nearby the digester, and digestate is temporarily stored there (several days).

Total capacity of all warehouses has to be sufficient to store digestate production of several months.

Volume of fresh manure storage $V_{sd}$is defined by the following equation:

$$V_{sd} = 180\ (Q_{ts}a) \tag{2}$$

where: Q_{ts} – the total daily volumetric flow of slurry, m^3/day; a - The degree of processing manure, %.

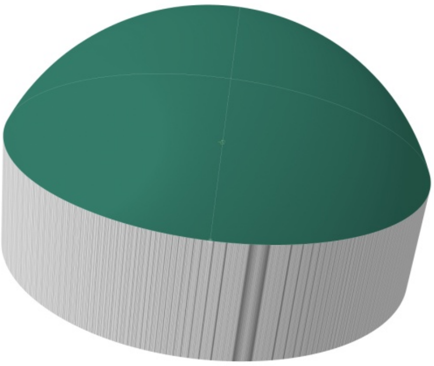

Fig. 3 Storage of digestate

Digester

Digester is an airproof tank in which AD (anerobic digestion) process takes place and biogas is being produced. During this activity, continuous digester has been used where the raw material constantly fills the digester, figure 4. Material passes through the digester whether mechanically or by pressure of newly put substrate that pushes out fermented material. Also, continuous digesters produce biogas without being interrupted for filling with new raw material and emptying the fermented residue. Continuous digesters produce constant and predictable amount of biogas and digestate. Vertical digesters are airproof, insulated, heated and equipped with mixers or pumps. They are mostly covered with concrete or steel roof, and biogas produced is carried to an outside warehouse nearby digester through pipes. In other cases, roof construction can behave as a membrane which is gasproof, and is simultaneously used as a warehouse for the biogas produced. Biogas either inflates the membrane or the membrane is fixed to the middle column.

Volume of digester V_{dig} is calculated by the following equation:

$$V_{dig} = k\ Q_{ts}\tau \tag{3}$$

where are: k - magnification factor volume for digester with fixed cover k = 1,2;Q_{ts} the total daily volumetric flow of slurry;

τ - recommended hydraulic retention time is τ = 15 days.

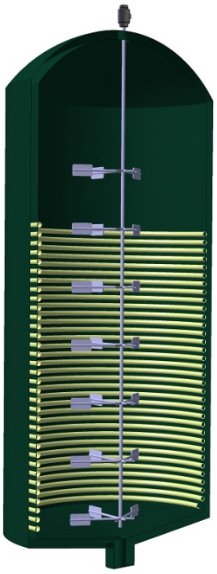

Fig.4.Anaerobic digester

Mixture technology

For the sake of mixing the new raw materials with the digester substrate, it is necessary to stir the mixture several times a day. This is a way of preventing to formation of floating crust and layers that sink down (sediments). Also,it bringsinto contact the bacteria (microorganisms) with particles of the new raw material and equalizing the distribution of heat and nutrients, figure 5.

Diameter of blade mixers$D_m$is calculated by the following equation:

$$D_m = 0.45 D_{dg} \tag{4}$$

where: D_{dg} – diameter of digester.

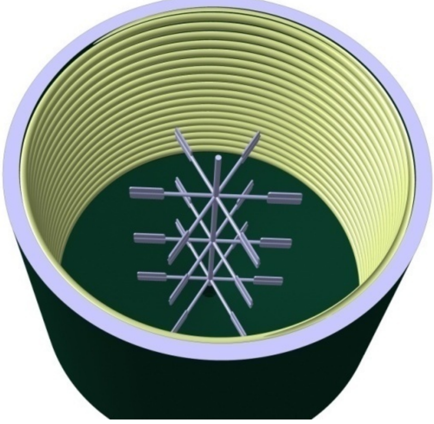

Fig.5.Mixers

Biogas warehouses and combustion torches

The exact selection and sizing of the biogas storage system-significantly contributes to efficiency and safety of biogas facility. An appropriate biogas warehouse ensures necessary supplies, reduces losses of biogas and contributes to security and safety of the biogas facility, figure 6.

In normal circumstances, it is recommended that capacity of the warehouse is equal to the biogas production per one or two days.

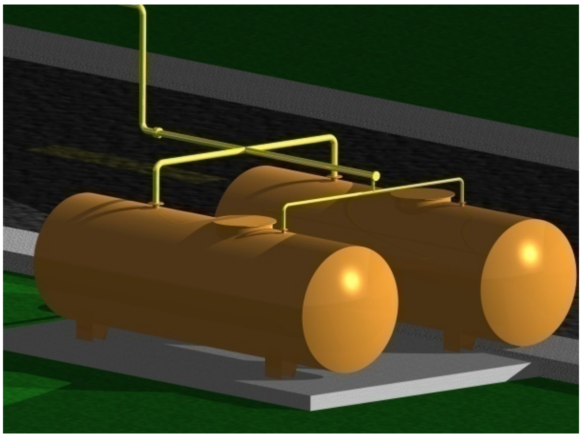

Fig. 6 Biogas storage tank

Combustion by torch is the final solution used in situations when surplus of the biogas cannot be stored or used for removing any sort of a risk for environment safety and protection, figure 7.

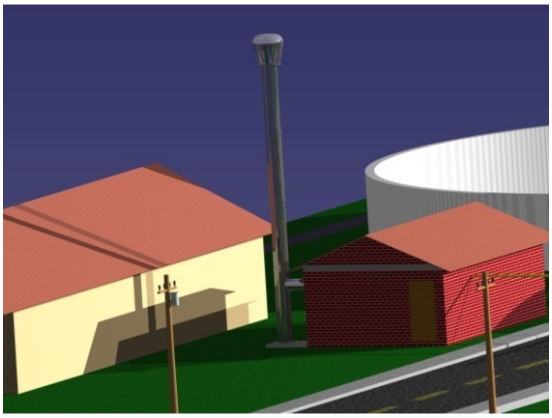

Fig. 7 The combustion torch and cogeneration facility

Biological desulphurization outside the digester

Reactor for biological biogas desulphurization (figure 8) is similar to the cleaning mop.

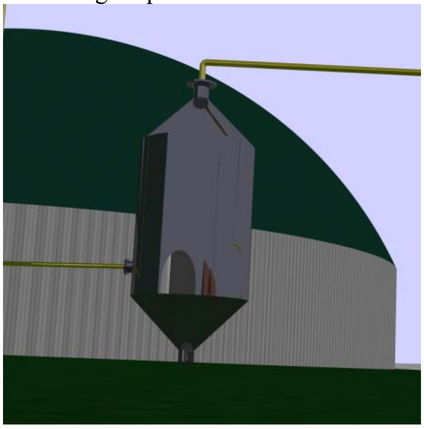

Fig.8. Scruber

It consists of the porous filling (plastic elements and similar are randomly deployed) in which microorganisms can grow.Also, the reactor contains precipitation tank andpumps and nozzles which are arranged to allow the regular spraying of charge. By injecting small quantities of atmospheric air upward, H_2S oxidation is caused via biological process, resulting in acid products or free sulphur.

Cogeneration, production of heat and electric energy

Combined heat and power (CHP) systems (also known as cogeneration) generate electricity and useful thermal energy in a single, integrated system (Jovanovski and Jovanovska, 2008).

Cogeneration production of electric and thermal energy is considered to be very efficient method for utilization of biogas. Before it is used in cogeneration plant, biogasis dried and conditioned. Most of the gas motors have their limitations regarding the contents of the hydrogen sulfide, halogenated hydrocarbons and siloxane which are contained in unprocessed biogas. Utilization degree of modern cogeneration generator is up to 90 percent, where electric energy production has a share of 35%, and thermal energy has a share of 65%.

Electric energy obtained from biogas can be used for electrical equipment such as pumps, control systems or mixers. However, in many countries where reduced price for the purchase of electricity from renewable resources is regulated (*feed-in* tariff), entire electric energy produced in a biogas facility is being sold into the network, and energy required for the facility is being purchased again from the network distributor, at lower cost.

Figure 8 shows the production of electric and thermal energy from a cogeneration plant, for several capacities of biogas facility. It has been noticed that, with increase in livestock, i.e. increase in the quantity of the substrate, production of electric and thermal energy has also significantly increased.

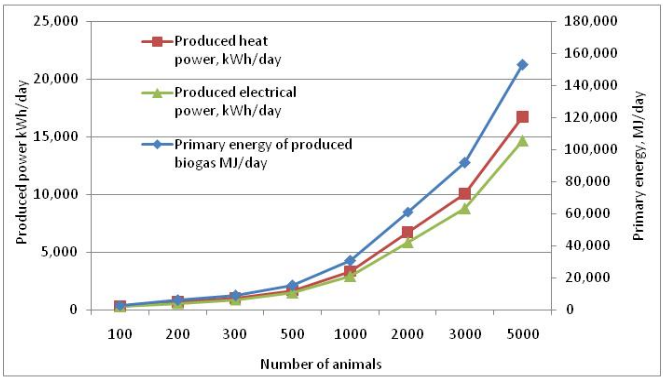

Fig.8. Produced electrical and thermal power in CHP

Table 1 shows produced energy from biogas plant. Also shows the profit realized from the sale of electricity by the feed-in tarife for Serbia 0.16 c€/kWh(Regulation of tariff in Serbia).

Figure 9 shows the electric energy sales profit, at preferential tariff of 16c€/kWh (Regulation of tariff in Serbia). Increase in livestock, i.e. increase in the quantity of the produced biogas leads to increase in electric energy sales profit. Also, when it comes to the amount of the electrical energy, the amount necessary for the system performance has not been taken into account.

Figure 10 shows repayment period for several different facilities depending on the number of working days per year. Investment cost and profits that are gained form electric energy sales have been taken into account. It is also important to highlight that large amount of thermal energy produced has not been taken into account.

Table 1. Characteristic of biogas plant

Number of animals	Biogas production [m^3/day]	Co-generation					
		Primary energy of produced biogas MJ/day	Produced heat power, kWh/day	Produced electrical power, kWh	Electrical power consumed by biogas plant, kWh/day	Heat power consumed by biogas plant, kWh/day	Profit from electricity, €/day
1	2	3	4	5	6	7	8
100	143.82	3,063.37	335.10	293.39	1.00	38	46.78
200	287.64	6,126.73	670.20	586.79	2.00	48	93.57
300	431.46	9,190.10	1,005.30	880.18	3.00	59	140.35
500	719.10	15,316.83	1,675.50	1,466.96	4.00	79	234.07
1000	1,438.00	30,629.40	3,350.54	2,933.52	9.00	128	467.92
2000	2,876.40	61,267.32	6,702.01	5,867.86	18.00	228	935.98
3000	4,314.60	91,900.98	10,053.02	8,801.78	27.00	327	1,403.97
5000	7,191.00	153,168.3	16,755.03	14,669.64	44.00	527	2,340.10

Table 2. The investiment price of biogas plant and repayment period in years (Zorg Biogas)

Number of animals	CHP Unit €	Equipment €	Construction €	Plant €	Repayment period, [year] (330 working days/year)	Repayment period, [year] (280 working day/year)	Repayment period, [year] (200 working day/year)
1	2	3	4	5	6	7	8
100	390000	470000	340000	1200000	78	92	128
200	390000	470000	340000	1200000	39	46	64
300	390000	470000	340000	1200000	26	31	43
500	390000	470000	340000	1200000	16	18	26
1000	390000	470000	340000	1200000	8	9	13
2000	442000	470000	340000	1252000	4	5	7
3000	540000	780000	490000	1810000	4	5	6
5000	660000	1090000	640000	2390000	3	4	5

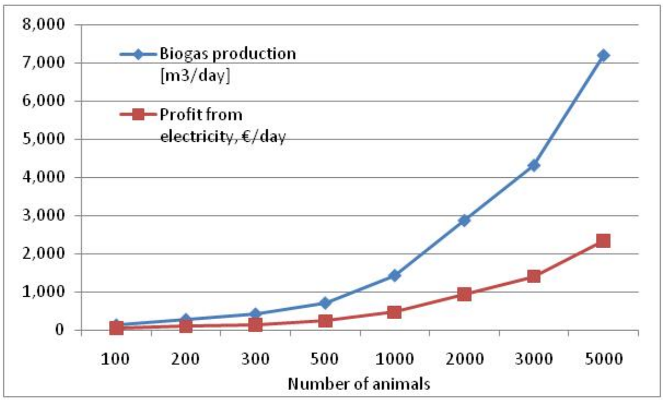

Fig. 9. Profit from electricity

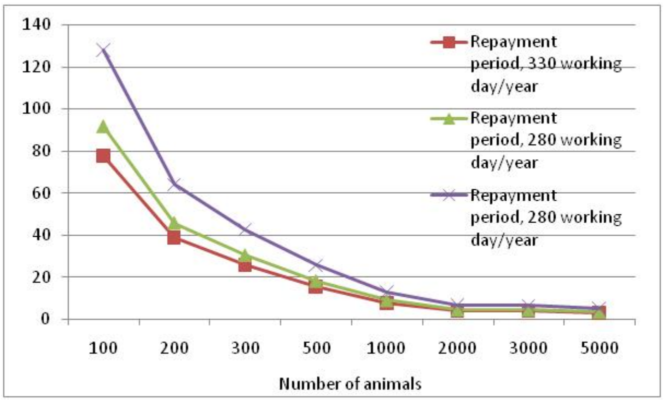

Fig.10. Repayment period by seelingelecitricity

Table 2 shows investment values for facilities of different capacities, and also repayment period in relation to sales of electric energy produced.

CONCLUSION

In this paper, parametric model of biogas facility has been presented, modelled in Catia V5 programme package. The model provided main components of a biogas facility such as: digester, manure warehouse, digestate warehouse, and scrubbers for biogas purification, tanks for biogas storage, cogeneration plant, combustion torches, lagoons and supporting infrastructure. Application of this model led to recognition of characteristics for several different capacities of facilities.

Research showed that construction of facilities of small capacities is not viable and repayment period would be too long. E.g. biogas facility with capacity of 300 livestock units and with 330 working days per year has a repayment period of 26 years, whereas facility with capacity of 3000 livestock units and with 330working days per year has a repayment period of only 4 years. It should be noted that heat obtained would remain unused, and with its usage, repayment period could be further reduced.

It is also very important to mention that interruption in plant operation significantly affects the profitability. E.g. facility with 3000 livestock units and with 330working days per year has a repayment period of 4 years, and if the number of working days would be reduced to 200, repayment period would be prolonged for another two years.

Eventually, research has shown that it is necessary to construct larger facilities, i.e. facilities with larger income of the substrate. Facilities should be built in locations where contingent usage of thermal energy gained from cogeneration biogas combustion is possible. The usage of thermal energy produced is important parameter for energetic and economic efficiency of the biogas facility. Thermal energy produced is partially used digester heating, and approximately 2/3 (two thirds) of total energy produced can be used for other purposes.

Attention should be paid to the number of working days of the facility, because with every non-working day its profitability isreduced.

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