EFFICIENCY OF BIOGAS UTILIZATION FOR COGENERATION

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The paper has the aim to study the opportunity of operating a cogeneration plant using biogas from waste treatment from poultry. The paper objective is to analyse the efficiency of animal waste treatment through anaerobic digestion and then utilization of generated biogas in a cogeneration plant. The performed analysis has included calculation of different technical and economic criteria. In the first part the paper presents different sources for biogas generation and technologies that can be used in a cogeneration plant. Further on the authors present a case study of biogas utilization in a cogeneration plant for electricity and heat production.

Keywords: biogas, energy, cogeneration, energy efficiency, economic efficiency

1. Sources of biogas generation

Biogas can be generated from any vegetal or animal matter including wastes. The raw material used for biogas generation can be of different proveniences.

The biomass from agriculture is:

- Different grass.
- Residues (tree leafs, roots, etc.).
- Industrial plants (sunflower, sugar beet, etc.).

Biomass from livestock:

- Animal wastes.

Municipal organic wastes:

- Waste water.
- Solid organic municipal residues.

Industrial organic wastes:

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- Food wastes.
- Agricultural wastes.
- Wastes from food industry.
- Fats, [3].

Biogas generated using anaerobic digestion is cheap and can be a valuable source of renewable energy. During the biogas combustion, a neutral CO_2 is produced. The biogas combustion allows treatment and recycling of different types of wastes and residues from agriculture, food industry, waste waters and leads to a sustainable attitude towards the environment, [4].

For analysis of biogas utilization in a cogeneration plant the paper shall analyse the agricultural sector, where for the biogas generation are used wastes from poultry. The reasons of this decision are the following:

- Valorisation of obtained biogas has multiple direct and indirect effects upon the community.
- By using biogas, it is replaced an important quantity of fossil fuel.
- Stabilisation of animal wastes that contain pollutant organic matters.
- Production of effluents that can be used in agriculture as fertilizers, [8].

2. Utilization of biogas for cogeneration

Combined production of heat and power (cogeneration) form biogas is considered an efficient way of its utilization. Before using biogas in a cogeneration unit, it is treated and dried. Most power units that can use biogas as primary fuel have maximal limits of sulphurous hydrogen, halogen hydrocarbons and other substances contained in biogas that is why it should be treated beforehand.

The most commonly used cogeneration technology for biogas utilization is based on internal combustion engine coupled with an electric generator. There can be different types of internal combustion engines. As alternative to internal combustion engines there can be used gas turbines, micro-gas turbines, fuel cells, but these technologies are still not very widely used for this purpose.

A very important issue regarding the energy and economic efficiency of a biogas unit is directly linked with utilization of generated heat. Usually, a great part of heat is used for heating the digesters, but about 2/3 of heat is available for external use. Formerly, many biogas units have been designed exclusively for power generation without utilization of excess heat. Today, utilization of available heat is considered very important since it can lead to improving economic efficiency of the unit. That is why new biogas units should also include possibilities of excess heat utilization, [5].

A biogas unit can be divided into two parts: one part includes all equipment for biogas generation and the second one includes equipment for energy generation. The biogas generation equipment consists of:

- Storage tank.
- Preparation tank.
- Digester.
- Biogas collection tank.
- Metering equipment.
- Biogas treatment equipment.
- Pumps.
- Heat exchangers.

3. Case study – utilization of biogas for cogeneration

3.1. Initial hypotheses

The technical analysis is based on the fact the animal waste treatment is compulsory and thus it is necessary to find an advantageous solution for biogas utilization.

The reference solution consists in waste treatment and generated biogas is burned at flare. For covering the energy needs of the farm, electricity is purchased from the National Power Grid, and heat is generated locally using a natural gas based boiler.

The cogeneration solution includes installation of an anaerobic digester, a storage tank, biogas treatment equipment and a cogeneration unit. For the short periods of time when cogeneration unit is not in operation the biogas is combusted in the boiler and the excess is burned at flare.

The cogeneration unit includes: biogas cleaning and drying equipment, cogeneration unit, heat exchangers and meters, [6].

For the analysed case study, there has been considered a poultry farm of 200000 of animals.

The analysis has been performed taking into account all technical hypotheses presented above. The poultry animal wastes have the advantage that they can be eliminated with high efficiency by using anaerobic digestion.

It has been estimated that the maximal annual operation time of cogeneration unit is 7870 h/year. Taking into consideration the lifespan of internal combustion engine, it results that for a project lifetime of 10 the cogeneration unit will a capital repair in year 6.

The annual operation period of cogeneration unit has been divided as follows:

- Winter days: 5125 h.
- Spring-autumn days: 2130 h.

- Summer days: 615 h.

3.2 Methodology

The technical-economic analysis included the following steps:

- Determination of daily energy potential of biogas.
- Determination of daily energy consumptions.
- Sizing of biogas valorisation equipment.
- Technical-economic analysis.
- Analysis of the results.

3.3. Aspects regarding economic analysis

Economic analysis allows taking a decision regarding efficiency of the analysed project. For the economic analysis there have been used criteria such as Net Present Value (NPV), Payback Period (PBP), Internal Rate of Return (IRR), etc., as shown below:

$$NPV = \sum_{i=1}^{n} \frac{IN_i - C_i - A_i - I_i}{(1+a)^i} \tag{1}$$

where: *INi* – revenues for year "*i*", *Ci* – expenses for year "*i*", *Ai* – anuitities for year "*i*", *Ii* – investement for year "*i*", a –a actualization rate, *n* – project analysis period.

$$\sum_{i=1}^{n_s} \frac{IN_i - C_i - A_i - I_i}{(1+a_0)^i} = 0 \tag{2}$$

$$IRR = a_0 \tag{3}$$

$$PBP = \frac{I}{IN - C} \tag{4}$$

Investment estimation

The project equipment includes the following: digester, cogeneration unit, biogas boiler, storage tank, biogas treatment equipment. The estimation of investments has been performed using specific investments for different types of equipment.

Maintenance expenses estimation

Biogas generation and valorisation involve expenses for equipment maintenance. These expenses are estimated taking into consideration specific costs for cogeneration equipment and biogas boilers.

Fuel and electricity expenses estimation

For cogeneration solution fuel expenses include money paid for natural gas needed for putting into operation internal combustion engine, for heating up the raw material until biogas is being generated (this latter part can be neglected for the summer time period).

For the analysed case study there has been considered that all generated electricity in cogeneration unit is sold into the grid with the aim of obtaining green certificates, which is the most economically advantageous, and all needed electricity for farm operation is purchased from National Power Grid.

Revenues estimation

The annual revenues are obtained from electricity generated by cogeneration unit and sold into the grid and money obtained from selling green certificates. The price of green certificate varies between 28.8 and 58.8 Euros. The number of green certificates varies depending on the technology used for biogas generation.

There has not been taken into consideration the rate of increase of electricity and heat prices. However, it should be mentioned that it would have led to better results of the analysed case study.

4. Results presentation and analysis

The results of the technical-economic analysis are presented in Table 1.

Table 1

Results of technical-economic analysis

Term	**Unit**	**Value**
Number of animals	-	200000
Efficiency of waste collection	%	95
Specific daily biogas flow	Nm^3/day/animal	0.01
Average methane concentration	%	60
LHV of biogas	kWh/Nm^3	6.3
Daily biogas flow	Nm^3/day	1149
Daily energy potential of biogas	kWh/day	7240
Hourly biogas energy	kW	301
Digester volume	m^3	2280
Engine installed power capacity	kWe	112.5
Engine installed heat capacity	kWth	143.8
Boiler installed capacity	kWth	250
Engine operation period		
▪ winter	h/year	5125
▪ spring-autumn	h/year	2130
▪ summer	h/year	615
Annually generated electricity by engine	MWhe	885375
Annually generated heat by engine	MWhth	1131706
Annually generated heat by boiler	MWth	0
Biogas excess burned at flare	Nm^3	0
Electricity annually purchased from	MWhe	0

grid		
Average electricity price from grid	€/MWhe	70
Heat price sold to farm	€/MWhth	30
Average electricity price to grid	€/MWhe	40
Minimal price for green certifiate	€/CV	28.8
Investment in digester	thousands €	234.84
Investment cogeneration unit	thousands €	90.90
Investment boiler	thousands €	23.75
Investment biogas treatment equipment	thousands €	6.32
Investment storage tank	thousands €	33
Works	thousands €	40
Engine capital repairs	thousands €	12
Total investment	thousands €	440.81
Annual maintenance expenses	thousands €	7.08
Annual expenses with purchased electricity	thousands €	18.22
Annual revenues green certificates	thousands €	76.5
Annual revenues with sold electricity	thousands €	35.42
Annual revenues with heat sold to farm	thousands €	16.98
Total annual revenues	thousands €	128.89
Net annual revenues	thousands €	103.59
Denomination rate	%	10
Project life-time	years	10
Denominated total costs	thousands €	596.42
Denominated total revenues	thousands €	792.65
NPV	thousands €	196.23
IRR	%	20
DPBP	years	2.2

The results of economic analysis lead to the conclusion that the analysed case study of biogas utilization for cogeneration is economically feasible with following particular aspect: the animal wastes from poultry farms are completely eliminated with higher efficiency compared to other solutions.

The obtained results lead to the following conclusions:

- The heat demand of agricultural farms can be covered integrally through valorisation of biogas from animal wastes.
- With some financial facilities cogeneration projects using biogas from animal wastes prove to be financially feasible.

5. Conclusions

Biogas valorisation, besides other bio-fuels, represents an important issue. Production of electricity and heat by using cogeneration technology based on biogas leads to lower environmental pollution and to increasing energy security of the country.

Romania meets all the conditions for generating biogas from wastes, and this is very important for future country's infrastructure. This is due to the following aspects:

- There is great potential for raw material for biogas generation.
- The necessity of upgrade of Romanian energy infrastructure can be a good start for investments.
- Due to new policies, there shall be a greater demand for energy generated from renewable energy sources.

The biogas generated from wastes can lead to avoiding CO_2 emissions with 2221000 tons till 2020 and with 5553000 tons till 2030. A greater contribution to avoiding emissions of green house gasses is that digestible wastes are no longer stored, thus there is no methane generation.

The electricity generation from CHP units based on biogas can also increase, thus leading to more power generated from renewable energy sources.

The main aspects that can influence the efficiency of biogas utilization for cogeneration are the following:

- The biogas units should be installed near the raw material source.
- The biogas unit is preferably to be placed near a community so the resulted secondary material can be sold to.
- The raw material supply should be ensured for at least 10-year period from own sources or through a very good established contract.
- The raw material should be checked for pollutants.
- The raw material should not vary very much in its characteristics and should have a steady flow.
- The biogas cogeneration unit should be build near a community with a possibility to sell the excess heat either for heating or technological purposes.
- The utilization of secondary products can lead to increasing economic efficiency of the project.

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