Matjaž Ošlaj, Bogomir Muršec

1 Introduction

Renewable energy sources are an integral part of the European Union fight against climate change while contributing to economic growth, job creation and increasing energy security. Among renewable energy sources are the biomass, solar, hydro power, wind energy and geothermal energy. It is essential to develop sustainable energy supply systems aimed at covering the energy demand from renewable sources [2, 28]. Renewable resources of energy are a part of the European battle against climate changes, at the same time they contribute to economic growth, increasing the number of employed people and provide energetic safety. Biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits [4] and is an additional source of income for farmers.

Biogas is derived from the anaerobic fermentation of organic matter such as manure, plants, food wastes, offal, etc... When that organic matter is stored without the approach, a biological process starts, resulting in biogas. Biogas from sewage digesters usually contains 55 % to 65 % methane, 35 % to 45 % carbon dioxide and <1 % nitrogen; biogas from organic waste digesters usually contains 60 % to 70 % methane, 30 % to 40 % carbon dioxide and <1 % nitrogen while in landfills the methane content is usually 45 % to 55 %, 30 % to 40 % carbon dioxide and 5 % to 15 % nitrogen. Typically the biogas also contains hydrogen sulphide and other sulphur compounds, compounds such as siloxanes and aromatic and halogenated compounds [3, 4, 6, 27].

When untreated or poorly managed, the animal manure becomes a major source of air and water pollution. Nutrient leaching, mainly nitrogen and phosphorus, ammonia evaporation and pathogen contamination are some of the major threats. The animal production sector is responsible for 18 % of the overall green house gas emissions, measured in CO₂, equivalent and for 37 % of the anthropogenic methane, which has 23 times the global warming potential of CO₂. Furthermore, 65 % of anthropogenic nitrous oxide and 64 % of anthropogenic ammonia emission originates from the worldwide animal production sector [21].

Animal manure is a major source of anthropogenic greenhouse gas emission (GHG), mostly as methane (CH₄) and nitrous oxide (N₂O). Concerning CH₄, livestock manure contributes 5–10 % of total emission [18]. In fact, the natural degradation of livestock wastes during their storage contributes 5–10 % of total emission [18]. In fact, the natural degradation of livestock wastes during their storage leads to the generator. The generator must be connected to public release of CH₄, to the atmosphere due to the anaerobic decomposition of the organic matter.

Among the many factors affecting the anaerobic digestion process, temperature is an important factor. Anaerobic digestion can proceed under psychrophilic (≤ 25 °C), mesophilic (25–40 °C) and thermophilic (> 45 °C) conditions. The digestion under thermophilic conditions offers many advantages such as higher metabolic rates, consequently higher specific growth rates but frequently also higher death rates as compared to mesophilic bacteria [7, 25, 26].

Protein, fat, fiber, cellulose, hemi-cellulose, starch and sugar markedly influence methane formation and are also the key factors for the methane yield from energy crops and animal manure [12].

The large amounts of animal manure and slurries produced today by the animal breeding sector as well as the wet organic waste streams represent a constant pollution risk with a potential negative impact on the environment, if not managed optimally. To prevent emissions of greenhouse...
gases (GHG) and leaching of nutrients and organic matter to the natural environment it is necessary to close the loops from production to utilization by optimal recycling measures (Fig. 1).

![Figure 1 Schematic representation of the sustainable cycle of anaerobic co-digestion of animal manure and organic wastes](image)

**2.1 Advantages of renewable energy**

**2.1.1 Renewable energy sources contribute to a safer supply**

Renewable energy sources are a better solution than the fossil tools [9].

Even renewable energy technologies, like any energy technology, have an impact on the environment. But their impact is much smaller than the impact of fossil and nuclear fuels. An important study of the EU notes that renewable energy sources in the light of climate change and possible catastrophic accidents at nuclear power plants have a generally significantly lower environmental impact. Renewable energy sources are the real solutions to climate change, but they should not be the only alternative. It is a set of modern energy options that provide cost-effective and reliable energy with less emissions of carbon dioxide. After extensive research and development and business orientation in the last 20 years, wind power, biomass heating and biomass, solar heating, solar and other renewable options become an important part of modern mix of energy sources. EU pursues objectives for 2020, which provide for a 12% share of renewables in total energy consumption to meet 95% CO₂ reductions needed to meet the Kyoto Protocol. The global challenge of environmental protection requires modified, environmentally oriented energy system for the future. In order to avoid catastrophic consequences for our planet, we need to slow down global warming. By the end of this century the average temperature from the time of the Industrial Revolution may be increased by more than 2 °C. It would be possible, it is necessary to significantly reduce greenhouse gas emissions. One of the key elements must be massive efforts to increase renewable energy sources [9].

**2.2 Biogas production**

The biogas can be used to meet on-farm heating needs via combustion in boiler, heater, or engine. It can also be used to meet electrical demands with the excess electricity having the potential to be sold to a local utility company. Unfortunately, in most instances of full-scale anaerobic digestion, the energy savings and potential revenue (i.e. current selling price of electricity) are not enough to provide a positive cash-flow. Thus, producers often explore the use of cost-share, grant monies, or other subsidiary support to off-set a portion of the capital and installation costs [5, 13].

The digestate can be sent to a solid–liquid separator with the liquid portion being utilized as a fertilizer. The separated solids can be composted to both stabilize them and convert them into a more useful product (Fig. 2).

There are many types of biogas plants in Europe, categorized according to the type of digested substrates, according to the technology applied or according to their size. The biogas plants digesting manure are categorised as agricultural biogas plants, and they usually co-digest manure and other suitable organic residues, many of them of agricultural origin, as well. A common classification of the agricultural biogas plants is: (1) the large scale, joint co-digestion plants and (2) the farm scale plants. There is not a sharp delimitation between these two categories as elements of technology from one category are also common to the other.

Figure 1. Schematic representation of the sustainable cycle of anaerobic co-digestion of animal manure and organic wastes [1].

Slika 1. Shematizki prikaz održivog ciklusa anaerobne ko-digestije stajskog gnojiva i organskog otpada [1].

**2.1.2 Renewable energy sources - the smallest environmental impact of all energy sources**

Obnovljivi izvori energije – najmanji utjecaj na okoliš od svih izvora energije.
The EU-countries where the agricultural biogas plants are most developed are Germany, Denmark, Austria and Sweden and to a certain level the Netherlands, France, Spain, Italy, United Kingdom and Belgium. The technology is under current development in countries like Portugal, Greece and Ireland as well as in many of the new, Eastern European, member states, where a large biomass potential is identified. Biogas can be produced from nearly all kinds of biological feedstock types, ranging from the primary agricultural sectors and from various organic waste streams from the overall community. The largest resource is represented by animal manure and slurries from cattle and pig production units as well as from poultry, fish, fur, etc. In the EU-27 alone, more than 1500 mill. tonnes of animal manure are produced every year (Table 1).

<table>
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<th>Country</th>
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<th>Pigs (1000 heads)</th>
<th>Cattle (1000 livestock units)</th>
<th>Pigs (1000 livestock units)</th>
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**Table 1 Estimated amounts of animal manure in EU-27 [10]**

### Flow diagram of anaerobic digestion process and end points of products

**Figure 2** Flow diagram of anaerobic digestion process and end points of products

**Slika 2.** Dijagram toka procesa anaerobne digestije i konačni proizvodi

2.3 The exploitation of biogas

Eksplotacija bioplina

Production of energy source by anaerobic decomposition of organic waste is the most important benefit of biogas technology. Production of biogas in rural areas can have several advantages, such as the release of its electricity, coal, fuel oil, wood for heating and avoiding problems with the administration and distribution network. Organic matters for biogas production are easily accessible and reduce the use of firewood and preserve forest. Polpraser (1996) [18] calculated that the total combustion of 1 m³ of biogas is sufficient to:

- two hour operation of engine with a 0.73 kW
- provide 1.25 kWh of electricity
- provide heat for cooking three meals a day for five persons
- provide 6 hours of light equivalent to one 60 W lamp
- an hour operation of cooler with a capacity of 1 m³
- half-hour operation of incubator with a capacity of 1 m³.

Any possibility of using biogas based on its combustion, like the biogas, as well as other combustible gases, offers a wide range of applications. The most
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common target users are the households and agricultural holdings. In households, the biogas can be used for cooking, lighting, heating (gas heaters, gas boilers), air conditioning, gas refrigerators, gas heaters for domestic hot water, etc. On farms, the possible uses of biogas are power tractors, hot water, the preparation of boiling water for heating greenhouses and other facilities, power stations, heating in the drying of agricultural products, etc. The continued use of biogas energy production by driving an electric generator with biogas produced electricity. Next, the energy use of biogas is in gas-fired steam boilers to generate steam for the drying of agricultural products, etc. The continued use of biogas technology, boiling water for heating and hot water for sanitation needs of people and animals on the farm [11].

Although most researchers believe that the biogas engine up to the daily influx of biomass below 10 LU is not profitable to build, small reactors are commercially available designed to use biogas from the daily waste from household and garden. Such reactors (for example, a reactor of a German manufacturer of synthetic material Vaupel Verfahrenstechnik) have a small production (maximum up to 8 m³ of biogas per month), which satisfies the needs of cooking in a smaller household [11].

Theoretical requirement of air for complete combustion of biogas is 5,7 m³ of air per 1 m³ of biogas [21].

2.4 Substrates for biogas production

To ensure optimal production of biogas input mixing of substrates depending on their ratio C : N [28] is important.

In practice, for these purposes, the municipal and industrial waste water, human and animal secretions, and (waste) biomass plant are most used. Basic requirements of these substances in the economical processing of biogas are:

- to have sufficient quantities available throughout the year,
- to have a composition (or containing substances which can break down the microbes) enabling efficient and economical production of biogas,
- do not contain substances that would act toxically or initiatory to the process of biogas production.

The whole spectrum can be divided into the following basic groups [23]:

- excrements of domestic animals and humans
- organic waste industry
- agricultural residues and by-products
- cultivated biomass
- sewage water.

The livestock produce large quantities of liquid waste materials or semi-liquid consistency. These waste materials can be an excellent raw material for production of biogas. Manure is composed of animal secretions, in addition, loose fees remains, straw or other litter materials, as well as inorganic materials. Slurry contains virtually no litter, but contains all the animal faeces and urine. From cows weighing 500 kg, we get about 15 m³ per year undiluted slurry [15]. The concentration of dry matter is essentially dependent on the method of cleaning the manure in stables and farming method. If growing the animals on the floor grate, the manure is drawn almost exclusively from stool and urine, so the concentration is 10-15 % of dry matter, or even more. If the cleaning takes place through water-jet, the dry matter concentration is only 5-8 % or less [11]. Pig manure from large farms has 2 to 4,5 % of dry matter, 40 to 120 % of water are added.

Mrhar et al. (1986) [15] found that removal of residues of roughage from liquid manure and slurry heated to a temperature of methanogenic anaerobic treatment does not affect the intensification of degradation processes. In their experiment, the biogas was even less than the "cold" process.

The systems of cattle slurry with the principle of selection of the most appropriate slurry depend on the anaerobic degradation potential use of biogas [17].

In higher dry matter content derives to a large proportion of suspended particles contact process which features the return of part of an active anaerobic biomass from boiled slurry into the reactor in order to speed up the process of degradation. For a very diluted slurry the anaerobic process can be used with floating layer or anaerobic filter [17].

The quantity of biogas which can be manufactured from various types of animal excrements and other agricultural wastes depends on the organic matter content and the degree of decomposition of organic matter in the process of anaerobic fermentation. The highest yields of biogas can be achieved by using household spent oils (800 m³/t substrate) [30].

In practice, the rate of degradation typically ranges from 40-50 % slurry, so that the expected production is 0,4-0,6 m³ of biogas per kilogram of organic compounds introduced into manure, or 0,8-1,0 m³/kg decommissioned organic constituents of manure [11]. Gačeša et al. (1985) [11] indicate that fat enables the production of maximum quantities of gas with a high content of methane, that the protein gives a somewhat lower amount of gas with a relatively low concentration of methane, and that carbohydrates give minimum amounts of biogas with low methane.

To estimate the amount of droppings, this can be obtained within a specified time period and used as feedstock for the production of biogas be performed, is a useful definition of the concept of "head"of livestock units (LU). Under LU the cattle are bred up to 500 kg weight born [11].

Various organic materials, which are placed in the process of anaerobic fermentation, give us different amounts of biogas. How will recovery of biogas, is conditioned by the mere structure of organic materials, in particular, the content of insoluble matter and the ratio C: N. If this ratio is not within the limits required, it must be corrected. Thus the conversion of the nitrogen content and the actual ratio of C: N for all types of organic matter was made [24].

2.5 Biogas Technology

The fermenter is the core of each biogas plant. It can degrade bacteria and decompose organic matter introduced.
This releases the desired biogas. Without treatment in biogas plants these persistent substances can degrade and be converted to smell, ammonia, and reduce the proportion of oxygen in the soil. The process of obtaining biogas as to provide a double environmental benefit: in addition to power generation, which does not burden the atmosphere with additional greenhouse gas emissions, the starting material for the substrate is processed so that there are also less other emissions and are more environmentally acceptable. This requires a well-functioning fermenter which must be designed as follows:

- Access of air and light must be prevented
- Containers must be watertight and gas-tight
- It must be warmed to the desired process temperature and its preservation and precise regulation (thermodynamic regulation) ensured
- Frequent and abundant mixing should prevent the formation of layers and zones
- We need to ensure a reliable input and output, as well as the movement of the substrate
- Adequate time of keeping the substrate in fermenter must be anticipated
- The inlet cold-larger quantities of the substrate at a time must be avoided
- Excessive amounts of inlet disinfectant substances must be avoided.

Biogas system consists of several components - in summary, the cave collecting substrate (manure, slurry, bio-waste). Dip cutter first weighs, grinds and mixes. The mass of the system is transferred (pumping station), then proceeds to the fermenter, which is heat-insulated, gas-tight and equipped with wall heating. Charging of the fermenter is generally performed twice daily. This fermentation process is different and depends on the composition of the substrate. Fresh slurry and then the added weight are pushed from the first to the second fermentor and from it through another pump shaft are pumped in the final slurry tank. Slurry after fermentation does not contain nitrates, it is a valuable bio-fertilizer, which does not cause scorching of green leaves and is almost odourless. Second fermenter is usually of the same size as the fermenter, gas-tight and equipped with a mixing device. As a general rule it is necessarily not warmed and is sun heat insulated. Here desulphurisation process with controlled air flows underway to prepare the biogas. Biogas from the second fermenter is stored in the gasometer which is designed to hold it, since production and use of biogas is not run simultaneously. The spectrum of substrates, the possibility of production and energy use of biogas are also expanding rapidly. The investors also set new challenges and risks faced by the Administration and various eco-sanitary and veterinary regulations and electrical permits.

2.6 Biomethanation of manure

Biometanizacija stajskog gnojiva

Anaerobic digestion is one of the technologies used to produce energy as well as to stabilise the waste. Energy production has remained an important factor, even with dropping energy prices. The atmospheric greenhouse effect, sustainable development and the ozone layer depletion have all contributed to the value of anaerobic digestion as a renewable energy source [19].

The utilisation of animal manure as a feedstock for biogas production will save plant nutrients and improve health conditions and quality of life in the villages [8]. Biogas is a CO₂ neutral fuel and the increase of biogas utilisation will achieve CO₂ and methane emission decrease. However this reduction will depend on careful handling of fresh and digested manure to avoid significant methane losses to the atmosphere.

Many researches have studied the biomethanation of cow manure in detail. Many studied the mesophilic and psychophilic digestion. Others studied thermophilic digestion [28]. Thermophilic digestion has many advantages over the mesophilic, such as higher metabolic rates, pathogen removal and improved physical-chemical properties.

3 Conclusions

Zaključki

There is a considerable potential of biogas production from anaerobic digestion of animal manure and slurries in Europe, as well as in many other parts of the world. Anaerobic digestion of animal manure offers several environmental, agricultural and socio-economic benefits through improved fertilizer quality of manure, considerable reduction of odours and inactivation of pathogens and last but not least production of biogas, as clean, renewable fuel, for multiple utilizations.
The last decade brought about huge steps forward, in terms of maturation of biogas technologies and economic sustainability for both small and large scale biogas plants.

One of the driving forces for integrating biogas production into the national energy systems will continue to be the opportunities offered by biogas from anaerobic co-digestion of animal manure and suitable organic wastes, which solves some major environmental and veterinary problems of the animal production and organic waste management sectors.

Rewarding manure processing for biogas production and for the environmental benefits provided by this would ensure the future development of the manure based biogas systems.

4 References

Reference


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