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BIOGAS AS A RENEWABLE ENERGY SOURCE

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Subject review

Renewable energy technology does not simply produce energy, heat and transport fuel, but also offers the opportunity to live in the footsteps of a reasonable future development. In Europe and other industrialized regions, the main reason for the development of renewable energy is the environment, in particular the concern in relation to global climate change and the need to improve security and diversity of energy supply. In the developing countries, they promise a new hope for renewable primary energy supply in regions without conventional energy and provide an opportunity for sustainable development. Production of "green energy" from biogas, which is among the renewable energy sources, promises an environmentally less damaging way of obtaining energy by reducing CO_2 emissions into the environment and reduces energy dependence on imported energy sources. Biogas production is of major importance for the sustainable use of agrarian biomass as renewable energy source.

Keywords: *anaerobic digestion, biogas, manure, renewable energy*

Bioplin kao obnovljivi izvor energije

Pregledni rad

Tehnologija obnovljivih izvora energije ne proizvodi samo energiju, toplinu i gorivo za transportna sredstva, već također nudi mogućnost života koji vodi razumnom budućem razvoju. U Europi i drugim industrijaliziranim područjima, glavni razlog za razvoj obnovljivih izvora energije je okoliš, posebice zabrinutost u vezi s globalnim klimatskim promjenama i potrebom za poboljšanjem sigurnosti i raznolikosti opskrbe energijom. U zemljama u razvoju, obećavaju novu nadu za obnovljive izvore primarne energije u regijama bez konvencionalne energije i pružaju priliku za održivi razvoj. Proizvodnja "zelene energije" iz bioplina, koja je među obnovljivim izvorima energije, obećava ekološki manje štetan način dobivanja energije smanjenjem emisije CO_2 u okoliš i smanjuje energetsku ovisnost o uvoznim izvorima energije. Proizvodnja bioplina je od velike važnosti za održivo korištenje agrarne biomase kao obnovljivog izvora energije.

Ključne riječi: *anaerobna digestija, bioplin, obnovljiva energija, stajsko gnojivo*

1 Introduction
Uvod

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 CO_2 equivalent and for 37 % of the anthropogenic methane, which has 23 times the global warming potential of CO_2. 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 (CH_4) and nitrous oxide (N_2O). Concerning CH_4, livestock manure 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 CH_4 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 psychophilic (< 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).

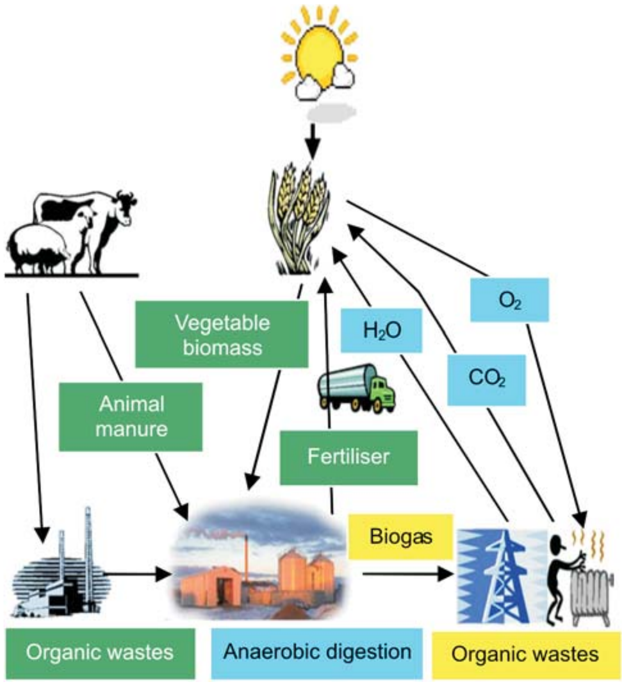

***Figure 1** Schematic representation of the sustainable cycle of anaerobic co-digestion of animal manure and organic wastes* [1]
***Slika 1.** Shematski prikaz održivog ciklusa anaerobne ko-digestije stajskog gnojiva i organskog otpada* [1]

2.1
Advantages of renewable energy
Prednosti obnovljive energije

2.1.1
Renewable energy sources contribute to a safer supply
Obnovljivi izvori energije doprinose sigurnijoj opskrbi energijom

Renewable energy can contribute significantly to secure energy supplies in Europe. Development of their use depends on the essential political and economic efforts. In the medium-term, renewable energies are the only source of energy with which the European Union has some flexibility to increase supply in the current context. These forms of energy cannot be ignored. All value-added processes are dependent on energy supply, and, hence, on energy prices. Even if the demand for energy remains at its current level, the majority of fossil fuels will be exhausted in the 21 century. Only the supply of coal is provided for more than 200 years [12]. In the long-term, it is clear that the price of supplies of fossil fuels will increase steadily. Variable price of conventional energy sources on the world market, especially oil, to a large extent undermines economic and political stability of much of the world and sometimes has dramatic impact on developing countries that import energy. In this context, renewable energy sources contribute to more diverse and secure energy supply. The renewable energy sources are a better solution than the fossil tools [9].

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

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 % CO_2 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
Proizvodnja bioplina

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.

Table 1 *Estimated amounts of animal manure in EU-27* [10]
Tablica 1. *Procijenjene količine životinjskog gnojiva u EU-27* [10]

Country	Cattle (1000 heads)	Pigs (1000 heads)	Cattle (1000 livestock units)	Pigs (1000 livestock units)	Cattle manure (10^6 tons)	Pig manure (10^6 tons)	Total manure (10^6 tons)
Austria	2051	3125	1310	261	29	6	35
Belgium	2695	6332	1721	529	38	12	49
Bulgaria	672	931	429	78	9	2	11
Cyprus	57	498	36	42	1	1	2
Czech R.	1397	2877	892	240	20	5	25
Denmark	1544	13 466	986	1124	22	25	46
Estonia	250	340	160	28	4	1	4
Finland	950	1365	607	114	13	3	16
France	19 383	15 020	12 379	1254	272	28	300
Germany	13 035	26 858	8324	2242	183	49	232
Greece	600	1000	383	83	8	2	10
Hungary	723	4059	462	339	10	7	18
Ireland	7000	1758	4470	147	98	3	102
Italy	6314	9272	4032	774	89	17	106
Latvia	371	436	237	36	5	1	6
Lithuania	792	1073	506	90	11	2	13
Luxembourg	184	85	118	7	3	0	3
Malta	18	73	11	6	0	0	0
Netherlands	3862	11 153	2466	931	54	20	75
Poland	5483	18 112	3502	1512	77	33	110
Portugal	1443	2348	922	196	20	4	25
Romania	2812	6589	1796	550	40	12	52
Slovakia	580	1300	370	109	8	2	11
Slovenia	451	534	288	45	6	1	7
Spain	6700	25 250	4279	2107	94	46	140
Sweden	1619	1823	1034	152	23	3	26
UK	10 378	4851	6628	405	146	9	155
EU-27	91 364	160 530	58 348	13 399	1284	295	1578

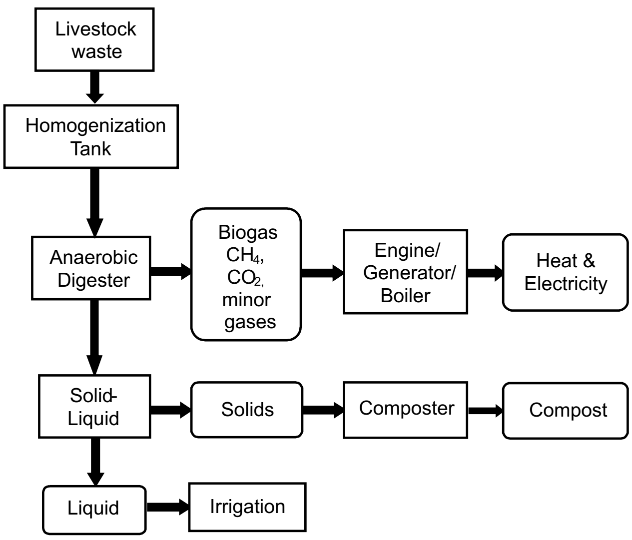

Figure 2 *Flow diagram of anaerobic digestion process and end points of products*
Slika 2. *Dijagram toka procesa anaerobne digestije i konačni proizvodi*

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).

2.3 The exploitation of biogas
Eksploatacija 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 m^3 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 m^3
- half-hour operation of incubator with a capacity of 1 m^3.

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 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 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 m^3 of biogas per month), which satisfies the needs of cooking in a smaller household [11].

Heat value of biogas depends on the content of methane and averages 6,0 kWh/m^3. Biogas is lighter than air and therefore cannot collect on the floor. On exit as compared to the rapidly mixing propane with air, it thereby reduces the risk of explosion. Ignition temperature of 700 °C is another advantage of safety in the work with biogas. The theoretical requirement of air for complete combustion of biogas is 5,7 m^3 of air per 1 m^3 of biogas [21].

2.4 Substrates for biogas production
Supstrati za proizvodnju bioplina

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 initiatorily 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 m^3 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 for 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 m^3 / 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 m^3 of biogas per kilogram of organic compounds introduced into manure, or 0,8-1,0 m^3/kg decommissioned organic constituents of manure [11]. Gaćeša 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
Tehnologija bioplina

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 (thermo-static 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.

Figure 3 *Gasometer in biogas industry in Nemščak, Slovenia*
Slika 3. *Plinometar u bioplinskoj industriji u Nemščaku, Slovenija*

Figure 4 *Modern industrial biogas Nemščak, in Slovenia*
Slika 4. *Suvremeni industrijski bioplin Nemščak u Sloveniji*

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 CO_2 neutral fuel and the increase of biogas utilisation will achieve CO_2 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
Zaključci

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
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