# PROIZVODNJA BIOGASA U REPUBLICI SRBIJI – TRENUTNO STANJE I PERSPEKTIVA

# BIOGAS PRODUCTION IN THE REPUBLIC OF SERBIA – CURRENT SITUATION AND PROSPECTIVE

**Zoran Štirbanović,**
University of Belgrade, Technical Faculty in Bor; zstirbanovic@tfbor.bg.ac.rs

*Aktuelna energetska kriza u svetu uticala je na veliko povećanje cena svih energenata i uslovila neophodnost prelaska sa konvencionalnih na nove, alternativne a ujedno i jeftinije i ekološki prihvatljivije izvore energije. Republika Srbija poseduje velike potencijale za proizvodnju energije iz obnovljivih izvora, koji nisu u dovoljnoj meri iskorišćeni iako je poslednjih godina napravljen značajan pomak u toj oblasti.*

*Biogas predstavlja proizvod anaerobne digestije otpada organskog porekla (stajsko đubrivo, poljoprivredni otpad, mulj iz otpadnih voda, gradski čvrst otpad ili bilo koja druga biorazgradiva materija) bez prisustva kiseonika. U sastavu biogasa se nalaze pretežno metan (50–75 vol%) i ugljen-dioksid (25–50 vol%). Kao produkti procesa anaerobne digestije nastaju i manje količine toplote, kao i đubrivo sa velikom količinom azota*

*U Republici Srbiji postoji veliki broj elektrana ukupno instalisane snage od oko 26 MW. Najveći broj elektrana je lociran na teritoriji Autonomne Pokrajine Vojvodine. Proizvodnja biogasa u njima se vrši iz različitih supstrata a najčešće korišćeni su stajnjak i silaža kukuruza. U radu je prikazana analiza trenutnog stanja u proizvodnji biogasa u Republici Srbiji, kao i perspektiva daljeg razvoja u ovoj oblasti.*

***Ključne reči:*** *Obnovljivi izvori energije; biomasa; biogas; anaerobna digestija; elektrana*

*The current world energy crisis has affected the large increase in prices of all energy sources and necessitated the transition from conventional to new, alternative and at the same time cheaper and more environmentally friendly energy sources. The Republic of Serbia has great potential for the production of energy from renewable sources, which are not sufficiently used, although significant progress has been made in this area in recent years.*

*Biogas is a product of anaerobic digestion of waste of organic origin (manure, agricultural waste, sewage sludge, municipal solid waste or any other biodegradable substance) without the presence of oxygen. Biogas contains mainly methane (50–75 vol%) and carbon dioxide (25–50 vol%). Smaller amounts of heat as well as fertilizer with a large amount of nitrogen are also generated as products of the process of anaerobic digestion.*

*In the Republic of Serbia, there are a large number of power plants with a total installed capacity of about 26 MW. The largest number of power plants is located on the territory of Vojvodina. The production of biogas in them is done from different substrates, and the most commonly used are manure and corn silage. The paper presents an analysis of the current situation in biogas production in the Republic of Serbia, as well as the prospects for further development in this area.*

***Key words:*** *Renewable energy sources; biomass; biogas; anaerobic digestion; power plant.*

## 1 Introduction

The production of energy from renewable sources represents the energy potential of every country, especially in the light of the current situation in the energy sector when the prices of all non-renewable (fossil) energy sources are at their historical maximum. The Republic of Serbia has a great potential in energy production from renewable sources, especially from biomass, hydro power, wind and solar energy. However, despite a certain increase in the production of energy from renewable sources in recent years, most of this potential is not used. In the structure of the planned production of primary energy in the Republic of Serbia for the year 2022, renewable energy sources

participate with 25%, while the estimated value for the year 2021 is 26% [1]. The largest share of that production refers to the production of thermal energy from biomass as well as the use of hydro potential of large reservoirs, while the production of energy from other sources is represented to a much lesser extent. Increasing the use of other energy sources such as solar, geothermal and wind energy, as well as increasing the production of biofuels, primarily biogas, could make the Republic of Serbia more energy independent.

Serbia, as a predominantly agricultural country, has great potential for the production of all types of biofuels. According to official data for the year 2020, the largest areas were planted with corn, wheat, sugar beet and sunflower, as well as potatoes, while in fruit growing, plums, apples and grapes are the most common. Animal husbandry is mainly characterized by the breeding of poultry, pigs, sheep and cattle [2]. These crops/farm animals or residues that remain after their cultivation and processing can be partly used for the production of biofuels: biodiesel, bioethanol and biogas.

While the production of biodiesel and bioethanol is still in its infancy, the production of biogas started around 2010, and the flywheel was achieved with the introduction of a feed-in tariff for preferential producers of electricity from renewable sources in 2016 [3]. Currently available capacities for biogas production are around 26 MW and most of the plants are located in the territory of the Autonomous Province of Vojvodina. Substrates for biogas production mainly come from corn production and livestock production residues. However, there are still great potentials for increasing biogas production from those and other substrates. The paper presents an analysis of the current situation in biogas production in the Republic of Serbia, as well as the prospects for further development in this area.

## 2 Production of biogas

Biogas is produced in a biological process by the formation of a mixture of gases, mainly methane (50-70 vol%) and carbon dioxide (25-50 vol%), from organic mass, anaerobically, i.e. without the presence of oxygen. In addition, biogas contains small amounts of hydrogen, hydrogen sulfide, ammonia and other trace gases. The composition is influenced by the substrates used, the fermentation process and various technical performances. The process of biogas production can be divided into several stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Figure 1).

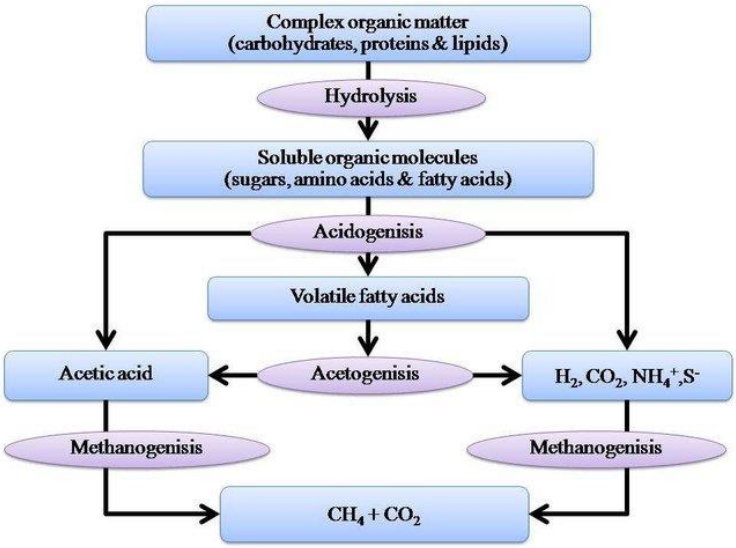


*Figure 1. Stages of biogas production [4]*

In the first phase, which is called hydrolysis, the complex compounds of the input raw material (eg carbohydrates, proteins, fats) are broken down into simpler organic compounds (eg amino acids, sugar, fatty acids). For this purpose, the hydrolytic bacteria involved in this process release enzymes that break down the organic matter biochemically.

The resulting intermediate products are then further decomposed in the acidogenesis phase by fermentative (acidogenic) bacteria into lower fatty acids (acetic, propionic and butyric acid) as well as carbon dioxide and hydrogen. In addition, small amounts of lactic acid and alcohol are formed. The type of products formed in this phase is influenced by the concentration of intermediately formed hydrogen.

These products are then converted into precursor substances of biogas (acetic acid, hydrogen and carbon dioxide), by acetogenic bacteria, as part of acetogenesis. In this context, the partial pressure of hydrogen is of great importance. Too high hydrogen content, for energy reasons, prevents the conversion of intermediate products of acetogenesis. As a result, there is an accumulation of organic acids, e.g. propionic, isobutyric, isovaleric and caproic acids and inhibition of methane formation. For this reason, they must form a close living community with methanogenic archaea, which during the formation of methane together with carbon dioxide consume hydrogen and thus provide acceptable environmental conditions for acetogenic bacteria.

In the next phase of "methanogenesis", the last phase of biogas production, primarily acetic acid as well as hydrogen and carbon dioxide are converted into methane by means of strictly anaerobic methanogenic archaea. Hydrogenetrophic methanogens produce methane from hydrogen and carbon dioxide, while acetoclastic methanogens form methane by splitting acids. Under the prevailing conditions in agricultural biogas plants, the formation of methane in the case of higher loads with organic matter mainly takes place in the reaction with hydrogen, and only in the case of relatively small loads with organic matter by decomposition of acetic acid.

## 3 Production of biogas in the Republic of Serbia

In the structure of the planned production of primary energy in the Republic of Serbia for the year 2022, renewable energy sources participate with 25%, while the estimated value for the year 2021 is 26%. In this structure, the largest share is solid biomass 61%, hydro potential 33%, wind energy 4%, while biogas, solar energy and geothermal energy participate with 2%. The planned use of biogas in 2022 for the production of electricity and heat is 0.052 Mtoe, which is 17% more than the estimated value in 2021 in the amount of 0.044 Mtoe [1].

The first plants for the production of biogas in the Republic of Serbia began construction in Blace, Čurug and Vrbas, in 2010, after the adoption of the Decree on the acquisition of the privileged status for a producer of electricity, which defined the conditions under which this status can be acquired as well as the price, i.e. feed-in tariff according to which the Public Enterprise Electric Power Industry of Serbia (EPS) will buy electricity from producers for a period of 12 years. The very fast and large growth of the biogas market in Serbia happened in 2016 after the adoption of a new Decree that removed the shortcomings that existed, causing that from only four plants built until 2016, today there is over twenty plants with about 26 MW of installed power.

However, at the beginning of 2020, the Decree on incentive measures for the production of electricity from renewable sources and from highly efficient combined electricity production ceased to be valid, which led to the fact that the operation of the biogas production plant is on the verge of profitability [5].

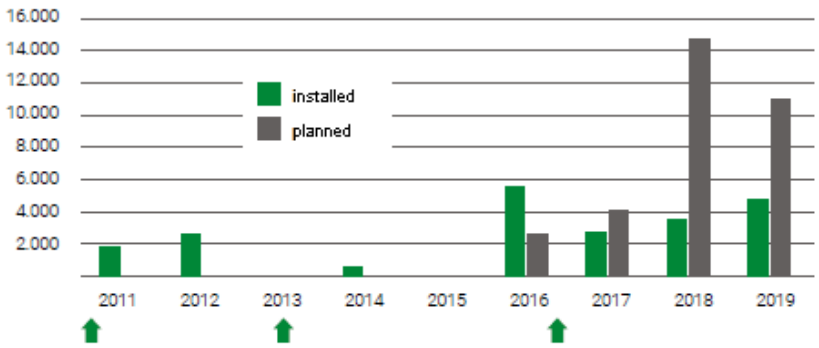


*Figure 2. Installed and planned capacities for biogas production in the Republic of Serbia in period 2011-2019 [3]*

Figure 2 shows the chronology of the development of biogas production in the Republic of Serbia for the period 2011-2019, through the planned and installed capacities of the power plants. As it can be seen the first power plants were built in 2011 and 2012 and their capacities were approximately 2 MW. In the period 2012-2016 there was a standstill in the construction of new plants due to unfavorable legal regulations related to this area. When in 2016 the new Decree was adopted to encourage the production of electricity from renewable sources, therefore, the production of biogas, there was a significant increase in newly installed capacities for its production.

*Table 1. Power plants for biogas production in the Republic of Serbia [6]*

| Power plant / place | Capacity | Used substrate | Year |
|---|---|---|---|
| Biospringer RS d.o.o. / Senta | 1738 kW | sludge from wastewater treatment plant | 2011 |
| Lazar d.o.o. / Blace | 999 kW | manure, waste from industrial processing of milk | 2012 |
| Mirotin-Energo d.o.o. / Vrbas | 1410 kW | manure, corn silage | 2014 |
| Bioelektra d.o.o. / Botoš | 600 kW | | 2016 |
| Biogas Energy d.o.o. / Alibunar | 3570 kW | corn silage, manure, barley | 2016 |
| BGS Beta BP d.o.o. / Bač | 650 kW | silage, manure, residues of agricultural products | 2016 |
| GBS Gamma BP d.o.o. / Bač | 650 kW | silage, manure, residues of agricultural products | 2016 |
| Gakovac d.o.o. / Stara Moravica | 2000 kW | manure, organic waste , corn silage | 2017 |
| Bioenergo 808 d.o.o. / Stara Pazova | 600 kW | manure, corn silage | 2017 |
| BGS Alfa BP d.o.o. / Bač | 650 kW | silage, manure, residues of agricultural products | 2018 |
| Bioelektro-NAK d.o.o. / Čestereg | 637 kW | corn silage, sorghum silage, rye, manure, sorghum | 2018 |
| Global Seed d.o.o. / Čurug | 1270 kW | manure, corn silage | 2018 |
| Envigas Alfa d.o.o. / Kanjiža | 800 kW | silage, manure, residues of agricultural products | 2018 |
| Envigas Beta d.o.o. / Kanjiža | 800 kW | silage, manure, residues of agricultural products | 2018 |
| AgroPlusEnergy d.o.o. / Svetozar Miletić | 999 kW | | 2019 |
| Forkom d.o.o. / Gornje Suhotno | 200 kW | plant production waste, sorghum silage, manure | 2019 |
| A.D. Budućnost / Bačka Palanka | 999 kW | corn silage, manure, organic waste | 2019 |
| Energo-Orahovo d.o.o. / Novo Orahovo | 999 kW | | 2019 |
| Panawis Plus d.o.o. / Čoka | 530 kW | | 2019 |
| Bio Pan Gas d.o.o. / Sečanj | 999 kW | corn silage, sweet corn waste, pig manure, beef manure | 2019 |
| MB ZLATAR d.o.o. / Mramorak | 1000 kW | solid and liquid manure, silage of corn, barley, rye, organic and non-hazardous waste | 2020 |
| Vinex Etil d.o.o. / Lukićevo | 2126 kW | Brewer's spent grain, manure, whey | 2020 |
| MB Bio Gold Energy d.o.o. / Mramorak | 1000 kW | solid and liquid manure, silage of corn, barley, rye, organic and non-hazardous waste | 2021 |
| MB Bio Life Energy d.o.o. / Crepaja | 1000 kW | solid and liquid manure, silage of corn, barley, rye, organic and non-hazardous waste | 2021 |

*Source: https://biogas.org.rs/biogas-sektor/biogas-elektrane-u-srbiji/*

In Table 1 are given power plants for production of biogas in the Republic of Serbia, along with their capacities, substrates they use for production of biogas and the year of commencement of work. As it can be seen power plant Biogas Energy d.o.o. from Alibunar built in 2016 has the highest installed capacity for production of biogas (3570 kW) and it uses corn silage, manure and barley as substrates. The second largest is Vinex Etil d.o.o. from Lukićevo (2020) with 2126 kW of installed power, which uses Brewer's spent grain, manure and whey for production of biogas, followed by Gakovac d.o.o. from Stara Moravica, built in 2017, which has the capacity for production of 2000 kW of biogas from manure, organic waste and corn silage. It also can be noticed from Table 1 that the most of plants use manure and corn silage as substrates for production of biogas and that the average capacities are from 600-1000 kW.

## 4 Possibilities for increasing the production of biogas in the Republic of Serbia

As it was said earlier, the main substrates for production of biogas in the Republic of Serbia are corn silage and cattle manure. Other agricultural crops or residues from their production and processing as well as other residues from farm animals breeding and industrial production of milk, beer, sugar or others products are used to a much lesser extent, thus leaving the possibilities for increase in biogas production.

The main agricultural crop in the Republic of Serbia is corn. In 2022, about 952,000 hectares were sown under corn. At the same time, about 650,000 hectares were planted with wheat, 250,000 hectares with sunflowers and 235,000 hectares with soybeans [7]. The average yields of the most important agricultural crops in the Republic of Serbia for the period 2016-2020 are shown in Table 2 [2].

*Table 2. The average yields of corn, wheat, sugar beet and sunflower in the Republic of Serbia [2]*

| Crop | Agricultural production (thousand tons) | | | | |
|---|---|---|---|---|---|
| | 2016 | 2017 | 2018 | 2019 | 2020 |
| Corn | 7377 | 4018 | 6965 | 7345 | 7873 |
| Wheat | 2885 | 2276 | 2942 | 2535 | 2874 |
| Sugar beet | 2684 | 2513 | 2325 | 2305 | 2018 |
| Sunflower | 621 | 541 | 734 | 729 | 637 |

According to the areas on which it is grown, corn has the highest average yields of about 7-8 million tons per year. The exception is 2017, when yields were much lower than the multi-year average about 4 million tons. Wheat yields are about 2/3 lower than corn yields, an average of 2.2-2.9 million tons. Crops such as sugar beet and sunflower can represent potential raw materials for biogas production, especially their residues after the production of sugar or edible oils.

The structure of livestock production in the Republic of Serbia for the period 2016-2020 is shown in Table 3 [2].

*Table 3. The structure of livestock production in the Republic of Serbia [2]*

| | Number of livestock (thousands) | | | | |
|---|---|---|---|---|---|
| | 2016 | 2017 | 2018 | 2019 | 2020 |
| Cattle | 893 | 899 | 878 | 898 | 886 |
| Pigs | 3021 | 2911 | 2782 | 2903 | 2983 |
| Sheep | 1665 | 1704 | 1712 | 1642 | 1685 |
| Poultry | 16242 | 16338 | 16232 | 15780 | 15249 |

As it can be seen from Table 3, cattle, pigs, sheep and poultry are the most represented in the structure of livestock production in the Republic of Serbia for the period 2016-2020. Since cattle manure (along with corn silage) is the most commonly used substrate for biogas production in the Republic of Serbia, it is possible to additionally increase biogas production from this source, but real potentials for the increase in biogas production comes from pig and poultry farms bearing in mind the quantum of livestock and the fact that these substrates were not represented in a large scale.

Table 4 shows the average yields of biogas and methane from different substrates. The qualities of substrates are subject to annual changes, which is why the data do not represent absolute values.

Data on biogas, i.e. methane, yields, are always given in standardized cubic meters ($Nm^3$). Since the volume of a gas depends on temperature and air pressure, volume standardization enables comparison of different operating conditions. The standard amount of gas refers to a temperature of 0 °C and an air pressure of 1,013 mbar.

*Table 4. The average yields of biogas and methane from different substrates [8]*

| Substrate | Biogas yield | Methane yield | Methane yield from organic dry matter |
|---|---|---|---|
| | $Nm^3$/t of substrate | $Nm^3$/t of substrate | $Nm^3$/t of oDM |
| Liquid cattle manure | 25 | 14 | 210 |
| Solid cattle manure | 80 | 44 | 250 |
| Liquid pig manure | 28 | 17 | 250 |
| Poultry manure | 140 | 90 | 280 |
| Corn silage | 200 | 106 | 340 |
| Silage of whole cereal plants | 190 | 105 | 329 |
| Cereal grains | 620 | 320 | 380 |
| Grass silage | 180 | 98 | 310 |
| Sugar beet | 130 | 72 | 350 |
| Fodder beet | 90 | 50 | 350 |
| Brewer's spent grain | 118 | 70 | 313 |
| Cereal pomace | 39 | 22 | 385 |
| Potato pomace | 34 | 18 | 362 |
| Fruit pomace | 15 | 9 | 285 |
| Crude glycerin | 250 | 147 | 185 |
| Rapeseed cake | 660 | 317 | 396 |
| Potato pulp | 80 | 47 | 336 |
| Sugar beet pulp pellets | 68 | 49 | 218 |
| Molasses | 315 | 229 | 308 |
| Apple pomace | 148 | 100 | 453 |
| Grape pomace | 260 | 176 | 448 |
| Green waste | 175 | 105 | 369 |

All of the substrates given in Table 4 can be used to additionally increase the current production of biogas but the use of some of them is limited due to technical possibilities or their use as livestock feed or in some industrial processes [8].

The yield of biogas from liquid cattle manure is 20–30 $Nm^3$ slightly below that from liquid pig manure. In addition, gas produced from liquid cattle manure compared to that produced from liquid pig manure has lower average methane content, and therefore a lower methane yield. This is due to the different composition of these organic fertilizers. Cattle liquid manure contains mainly carbohydrates, while pig liquid manure contains mainly proteins, which give higher methane content.

Corn is particularly suitable for use in biogas plants due to high energy yields per hectare and good fermentation properties. Almost all types of cereals as well as their mixtures (if their ripe comes at the same time) are suitable for production of silage from whole cereal plants. The most commonly used for this purpose are rye or triticale. Cereal grains, as a complement to existing substrates, are particularly suitable for use in biogas plants. Due to the high yields of biogas they provide and their rapid degradability, they are particularly suitable for precise management of biogas production. The type of cereal is not important.

By-products from biodiesel production, such as rapeseed cake and crude glycerin, are suitable as co-substrates for agricultural biogas plants. The height of the gas yield in rapeseed cake largely depends on the remaining oil content, which depends on the settings of the oil presses and the oil content in the raw material. During the production of one ton of biodiesel, about 2.2 tons of rapeseed cake and 200 kg of glycerin are produced. However, their use is associated with certain problems that need to be examined in detail in advance. The reason for this lies in the fact that during the fermentation of rapeseed cake, high contents of hydrogen sulfide ($H_2S$) are formed in the biogas, which is due to the high content of protein and sulfur in the rapeseed cake. The problem with crude glycerin is that it partly contains over 20 percent by weight of methanol, which in high concentrations has an inhibitory effect on methanogenic bacteria. For this reason, glycerin should only be introduced into the process in low doses.

According to calculations of biogas production from different substrates given by Cvetković et al. (2014) [9], the Republic of Serbia has real potentials for increasing its current production (Table 5).

*Table 5. Potentials of biogas production from different substrates by Cvetković et al. (2014) [9]*

| Substrate | Biogas potential (million $m^3$/year) |
|---|---|
| Agricultural crops directly provided for energy | 1635.8 |
| Municipal Solid Waste (MSW) | 95.6 |
| Cattle manure | 123.1 |
| Pigs manure | 47.8 |
| Poultry manure | 10.0 |
| Slaughterhouse Waste | 19.1 |
| Milk processing industry | 6.2 |

As it can be seen from Table 5, the highest potential for biogas production comes from agricultural crops directly provided for energy (1635.8 million $m^3$/year). Cattle manure and municipal solid waste also have high potentials with, 123.1 million $m^3$/year and 95.6 million $m^3$/year, respectively, followed by pig manure (47.8 million $m^3$/year), slaughterhouse waste (19.1 million $m^3$/year) and poultry manure (10 million $m^3$/year), while milk processing industry has o potential for production of 6.2 million $m^3$/year of biogas. However, these data should be taken with a certain reserve because in the meantime, a lot of plants have been built that use some of the given substrates.

## 5 Conclusion

The Republic of Serbia imports large quantities of fossil fuels, primarily oil and gas, and to a lesser extent coal. Considering the current energy crisis and the record prices of both energy products and electricity on the world market, one of the possible solutions for reducing energy dependence is the use of renewable energy sources.

Biogas has been produced in the Republic of Serbia since 2011, when the first plant with a capacity of 1.7 MW was built. To date, over 20 plants have been built with an installed capacity of over 26 MW. The most commonly used substrates for biogas production in the Republic of Serbia are corn silage and cattle manure.

Bearing in mind the structure of agricultural production, as well as the industrial processing of various agricultural crops, there are certain potentials for increasing the production of biogas from different substrates. In order to achieve this, financial and logistical assistance from the state is necessary.

## 6 Acknowledgment

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## 7 References

[1] *Energy balance of the Republic of Serbia for the year 2022*, Ministry of Mining and Energy of the Republic of Serbia, 2022. - *In Serbian*

[2] *Statistical calendar of the Republic of Serbia in 2022*, Statistical Office of the Republic of Serbia, 2022. - *In Serbian*

[3] **Pomoriški, Z.**, *Biogas as a potential for the development of local governments*, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Belgrade, Serbia, 2020. - *In Serbian*

[4] **Ramaraj, R., N. Dussadee**, Biological purification processes for biogas using algaecultures: A review, *International Journal of Precision Engineering and Manufacturing-Green Technology, Volume 4* (2015), 1-1, pp. 20-32.

[5] **Ećim-Đurić, O., D. Kreculj, D. Živojinović, M. Vorkapić**, *Potential of agricultural biomass in biogas production systems in the Republic of Serbia*, Proceedings 8th International Conference on Renewable Electrical Power Sources, Serbian Union of Mechanical and Electrical Engineering, Belgrade, Serbia, 2020. pp. 63-70.

[6] https://biogas.org.rs/biogas-sektor/biogas-elektrane-u-srbiji/

[7] *Expected production of wheat, raspberries and cherries and the sown area of corn, sugar beet, sunflower and soybeans, as of 23.05. in 2022*, Ministry of agriculture, forestry and water management of the Republic of Serbia, 2022. - *In Serbian*

[8] *Handbook on biogas - from production to use*, Expert agency for renewable resources, registered association (FNR), 2016. - *In Serbian*

[9] **Cvetković, S., T. Kaluđerović Radoičić, B. Vukadinović, M. Kijevčanin**, Potentials and status of biogas as energy source in the Republic of Serbia, *Renewable and Sustainable Energy Reviews, Volume 31* (2014), pp. 407-4016.