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*Djatkov Dj., Viskovic M., Martinov M., Nesterovic A., Bojic S.,
Venus T., Effenberger M.*



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Initiative on small biogas facilities for manure to attain

GHG mitigation in agriculture

(Biogas initiative)

This project is part of the European Climate Initiative (EUKI). EUKI is a project financing instrument by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The EUKI competition for project ideas is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions.

The opinions put forward in this brochure are the sole responsibility of the authors and do not necessarily reflect the views of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

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Authors:



Djordje Djatkov, Miodrag Viskovic, Milan Martinov, Aleksandar Nesterovic, Savo Bojic, (Faculty of Technical Sciences– FTS, Department of Environmental Engineering and Occupational Safety and Health, Novi Sad, Serbia)



Bayerische Landesanstalt für Landwirtschaft

Mathias Effenberger, Thomas Venus (Bavarian State Research Center for Agriculture– LfL, Institute for Agricultural Engineering and Animal Husbandry, Freising, Germany)

Foreword

This brochure is one of the outcomes of the project ***Initiative on small biogas facilities for manure to attain GHG mitigation in agriculture (Biogas initiative)***. This project is part of the European Climate Initiative (EUKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The project's goals are to raise awareness and educate target groups, transfer knowledge from Germany to Serbia, and initiate the technology implementation in Serbia. The project partners include the Faculty of Technical Sciences (FTS), Novi Sad, Serbia, and the Bavarian State Research Center for Agriculture (LfL), Freising, Germany.

This brochure addresses farmers, ministries, and professionals in the fields of renewable energies, agriculture, or environmental protection, as well as the public. Its purpose is to inform these target groups about the importance of small biogas plants for mitigating greenhouse gas (GHG) emissions from animal husbandry.

The brochure contains general information about small biogas plants, while it omits legal, technical and financial details. It also includes general facts and figures about animal husbandry, manure potentials, GHG emissions from livestock, and the biogas sectors in Germany and Serbia. Further comprehensive analyses about prerequisites for the successful implementation and potential effects of small biogas plants in Serbia are conducted within other project activities.

What are small biogas plants?

Within this brochure and the project Biogas initiative, “small biogas plants” are defined as installations on smaller farms that predominantly use livestock manure and where the produced biogas is utilized on site for combined electricity and heat generation. Low-tech installations that use organic waste and excrements from individual households, widespread in rural China and India, are not addressed. In such cases, the biogas is directly used for cooking, lighting, or heating.

In Germany, small biogas plants were first defined as installations that use a minimum share of 80% animal manure on a fresh-matter basis in the input and operate a generator with a nominal electric power output of up to 75 kW [1]. Based on these specifications, they are legally qualified to obtain a guaranteed tariff for grid feed (“feed-in” tariff) of their electricity output, as the basis for profitability. The biogas that can be produced from the liquid manure of 100 cattle units (CU) is sufficient to produce about 15 to 18 kW electric power output. Accordingly, a biogas installation sized for an output of 75 kW, requires about 500 CU, excluding by-products or wastes from agriculture and food-processing as additional input materials for biogas production.

In Serbia, small biogas plants are not defined and supported as a separate category within the existing and planned legislation on renewable energies [2,3,4]. Also, specific information for Serbia on this topic is not available from the literature. Thus, this project aims to investigate the potential for small biogas plants, their optimal size range, and the prerequisites for their successful implementation.

Small biogas plants predominantly use animal manure as a substrate for biogas production. In Germany, they receive a special guaranteed feed-in tariff for electricity generation up to 75 kW output, in case at least 80% of the fresh matter input is from animal manure. If biogas is produced solely from cattle manure, 100 livestock units can supply about 15 kW electric power output. In Serbia, the existing legislation neither defines nor supports small biogas plants.

Why are small biogas plants important?

In Germany, 9,527 biogas plants operated as of 2019, with a total capacity of 5,000 MW electrical power output [5,6]. Thus, about half of all biogas plants in Europe are currently located in Germany. However, the 520 installations with an electric power output of up to 75 kW and an additional 430 installations of up to 150 kW, small biogas plants are the minority [7]. More than one third of small biogas plants are located in Bavaria. Overall, less than 30% of total livestock manure in Germany is supplied to biogas plants [8], and animal manure remains unused particularly on small farms.

In Serbia, 22 biogas plants operated as of 2019, with a total installed electric capacity of 21.21 MW [5]. Most of these have an electric power output of around 1 MW, a few with 500 to 650 kW, and one with 200 kW [9]. Together, these plants used around 175,000 t/a of liquid manure equivalent, which is less than 1% of the total livestock manure potential in Serbia [10]. Thus, the overall share of animal manure that is properly treated in Serbia is negligible so far, and on small farms it is zero.

Livestock manure is used mostly as an organic fertilizer on agricultural land, but the current management practices cause significant negative environmental impacts. Most of the total livestock manure potential is distributed among many small farms. As a result, the mitigation of negative environmental impacts from manure management is an important driver to construct small biogas plants.

Small biogas plants are a key technology for the appropriate treatment of manure from small farms, which account for the larger share of the total manure potential. Manure is primarily used as an organic fertilizer on agricultural land, but current manure management practices cause significant negative environmental impacts. The construction of small biogas plants could substantially mitigate these impacts.

What are the environmental impacts of manure?

Manure consists of livestock faeces and urine. The mixture of both substrates is called “liquid manure”. When faeces and urine are diluted with water they form “animal slurry”, with very high water content depending on farm practices. Alternatively, a mixture of faeces, part of the urine, and straw for bedding form “solid manure”.

In principle, animal manure is a valuable organic fertilizer. However, if it is not adequately managed, it can be a source of environmental pollution and a threat to public health. In particular, if it is applied to agricultural land in excessive amounts, it can contaminate water resources and result in detrimental effects on soil.

The handling and storage of manure is recognized as a significant source of GHG emissions, directly in the form of methane (CH_4) and indirectly in the form of nitrous oxide (N_2O) after application to agricultural land. Globally, emissions of non- CO_2 GHG from agriculture amount to about 5.5 Gt $\text{CO}_{2\text{eq}}$ per year or 11% of total GHG emissions [11], of which a significant portion originates from manure management.

In Serbia, direct GHG emissions from manure management contribute 35% to the total emissions from animal husbandry [12]. Therefore, a significant share of 30 million tons of manure from all livestock in Serbia should be managed in environmentally safe manner. As there are many family-owned farms with only a few up to a hundred CU, the development of small biogas installations in Serbia for the sustainable use of manure represents a significant challenge.

Inappropriate storage and disposal of animal manure leads to negative effects on the environment, particularly on soil, water, and air. Methane and nitrous oxide emissions from manure contribute to global warming. To protect the environment and mitigate climate change impact, it is imperative that as much manure as possible is used in biogas plants.

What are the challenges?

A small biogas plant incurs high specific investment cost. In Germany, the average investment cost of a biogas plant with 75 kW of electric power output is 9,000 €/kW, as opposed to an installation with 1,000 kW which incurs an average investment cost of 3,750 €/kW [13]. Operators can lower these investment costs to around 5,500 €/kW for small plants by contributing significantly to the construction. At the same time, the efficiency of electricity generation is lower and rates up to 35%, compared to values of up to 44% for large generators [14].

Thus, as small biogas plants incur more than double the specific investment costs and yield 20% less electricity than large biogas installations, electricity prices must be substantially higher for small biogas plants in order for them to be profitable. Accordingly, the special remuneration for small biogas plants is about 23 c€/kWh in Germany. For larger plants, the participation in a tender process (“Pay-as-bid”) with a current ceiling price of about 14.4 for existing plants and 16.4 c€/kWh for new installations determines the price [15].

If substrates other than liquid manure are used (e.g., energy crops, chicken manure, feed / crop residues, etc.), additional devices are needed for substrate pre-treatment and feeding / mixing of the digester. In such cases, the investment and operating costs are higher [14]. This is a drawback, as a 75 kW plant that uses solely liquid manure requires a significant number of livestock (500 CU). Thus, for smaller farms, there are limited opportunities for profitable biogas production.

Further, the energy required for heating the digester is higher for small biogas plants treating mainly liquid manure, as the substrate contains more than 90% water. To increase the electrical capacity and provide sufficient heat energy for all consumers, co-digestion of solid substrates during the cold season can be an option. On the downside, this increases investment costs for substrate handling, while the larger capacities of the digester and the cogeneration unit cannot be fully utilized throughout the year.

Compared to larger biogas installations, small biogas plants face the challenge of relatively high specific investment costs and considerably lower electrical efficiency. Options to increase the plant's capacity due to a lack of manure or to improve energy efficiency result in increased investment and operating costs. Thus, small biogas plants require higher subsidies in order to operate profitably.

What are the benefits?

Small biogas plants generate environmental and socio-economic benefits. As the positive environmental effects were explained above, in this section it will be described how small biogas plants can benefit farmers and farm management.

Primarily, a small biogas plant generates income for farmers through the sale of electricity. Exemplary calculations from Germany for biogas plants with electric power output of 75 kW that use solely liquid manure as substrate indicate a net annual income of up to 38,500 € [14].

Due to the higher energy demand for heating the digesters, there is limited surplus heat available from small biogas plants for external uses, particularly during the cold season. Nevertheless, the heat output may be sufficient to replace the conventional heating of the farmhouse and farm buildings. Despite the low thermal power output of small biogas plants, most of the heat could be available for alternative uses in summer if this meets consumers' capacities.

At best, the biogas plant can be integrated into existing farm infrastructure. For example, the manure collection pit including pumps and pipes can be used to feed the biogas plant, while the holding tank for liquid manure can be used for digestate storage.

The labour input for small biogas plants is rather low with no need to employ new staff. The average additional labour input for a small biogas plant is estimated at around 30 min per day [14].

Apart from environmental protection, farmers can draw socio-economic benefits from small biogas plants. Namely, there is opportunity for additional income and energy cost savings.

Good practice

In this section, two farm-based, small biogas plants in Germany are presented. The first one features a rather simple configuration with the aim of minimizing the investment cost [16]. The second one was specifically designed to treat a large share of solid substrates from organic farming [17].

Example 1

This plant, commissioned in 2009, uses mostly liquid animal manure and achieves effective heat utilization on site. This results in high savings of GHG emissions. For planning and construction, the aim was to preferably utilize own capacities, local services, and affordable equipment to minimize the cost of construction. Reliable economic data are not available as it was not possible to disaggregate the plant costs from those of the rest of the farm.

The average daily substrate input rates 15.3 t and is comprised mainly of liquid manure from 120 dairy CU. The remaining 18% of substrate inputs consist of rye, corn, and grass silage. The liquid manure is pumped into the primary digester directly from a canal below the cattle stable. A simple device with horizontal screws and a hopper with 7 m³ capacity is used to feed solid substrates into the digester.

The primary and secondary digester each have a working volume of 800 m³ and are heated to a temperature of 40 °C (mesophilic temperature level). The approximate hydraulic retention time of the substrates in the digesters is 120 days. Given the high share of liquid cattle manure, there are no issues with instability of the digestion process. The digested residue is stored in the former manure storage pits, which in sum have a capacity of 730 m³.

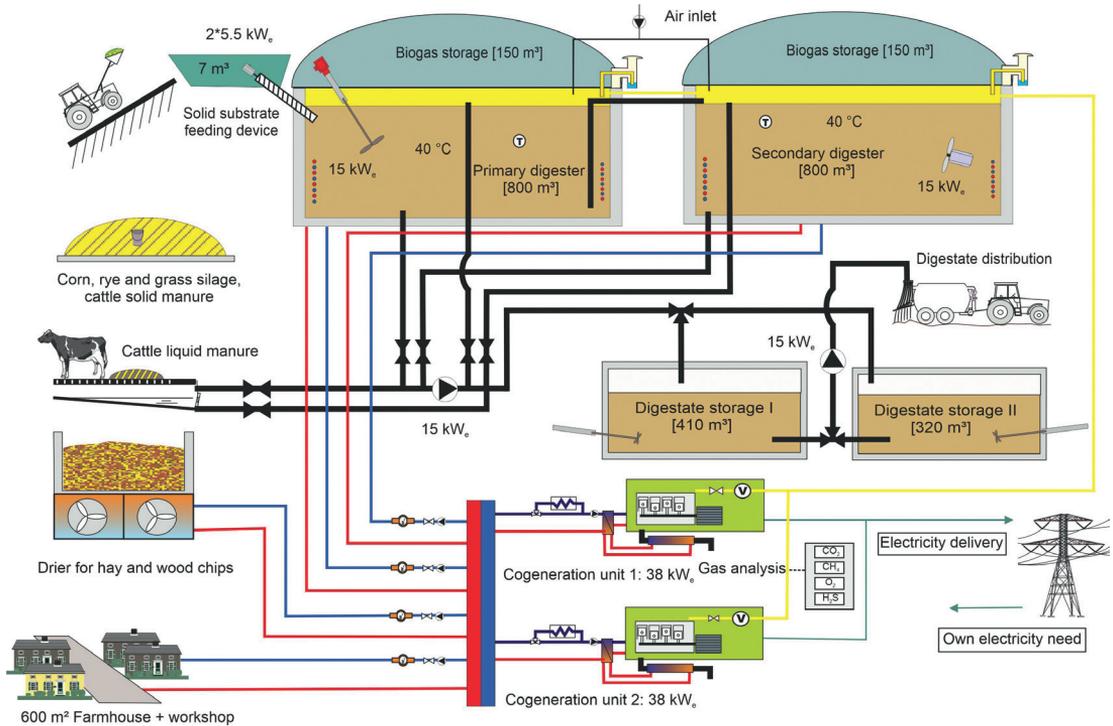


Figure 1. Scheme of a small biogas plant – Example 1 [16]

The biogas is utilized in two gas engines with a total electric power output of 76 kW. About 1,830 kWh/d of electricity is completely fed into the grid. The own electricity demand of about 10% is supplied from the grid, as it is cheaper to purchase. The demand for heating the digesters is about 30% of the heat output, and the surplus heat is utilized to heat the farmhouse and adjacent buildings, as well as to dry hay and wood chips.

Example 2

This plant was commissioned in 2016 and integrated into an organic agricultural farm to improve economic and environmental performance. The substrate mixture is comprised of solid cattle manure and liquid pig manure, each with about 41% of total input mass. The remaining input is mostly from clover grass silage. Daily input rates about 15 t, with an average dry matter content of 20%. Liquid manure is pumped into the digester from a 300 m³ storage tank, and the solid substrates are fed through a device with 12 m³ capacity mounted on top of the concrete cover of the primary digester.

The primary digester has a working volume of 850 m³ and the secondary one has 1,400 m³, with an integrated gas storage of 450 m³. The digesters are heated to a temperature of 44 and 38 °C, respectively (mesophilic range). The overall hydraulic retention time is 150 days on average, in fulfilment of the minimum requirement by law, so the digestate storage with a capacity of 1,800 m³ does not need a gastight cover.

The cogeneration unit with gas engine has a nominal electric power output of 75 kW and an electric efficiency of about 37%. The complete electricity output of 1,780 kWh/d is fed into the grid. The plant's own energy demand, in relation to its energy output, is 10% for electricity and 19% for heat. Over the year, about 22% of the generated heat amount is utilized for heating the pig stable, farm buildings, and four apartments.

The total investment cost amounted to about 550,000 €. The average annual income is 168,500 €, of which 87% is from electricity sales to the utility company, and the remainder from digestate and heat valorisation. The annual costs are around 110,500 €, where of 23% arise from substrate supply, 40% from depreciation, 31% from operating costs, 6% from labour costs.

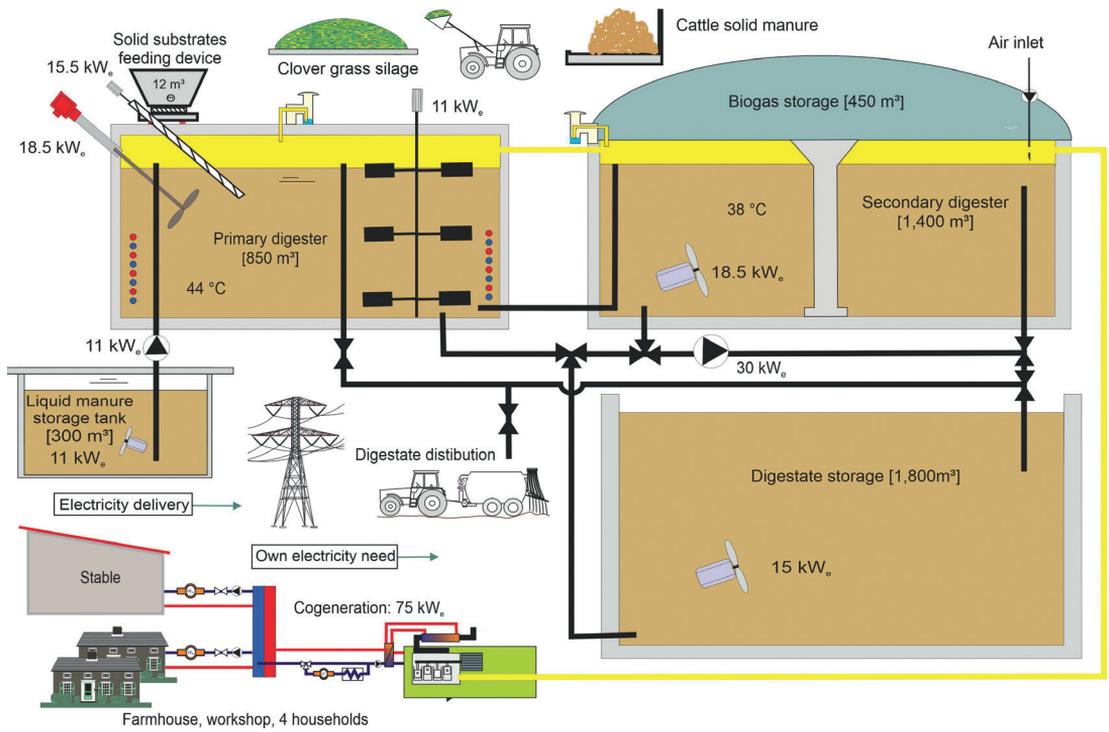


Figure 2. Scheme of a small biogas plant – Example 2 [17]

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