Assessment and prospects of biogas use

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Abstract. This article reveals the relevance of the use and development of an alternative source of heat and power supply, which is biogas. The potential of such a clean energy source is very great. The demand of countries for biogas is different, but it is constantly increasing every year. It opens up a platform for a variety of services that depend on economic and political priorities. Biogas can provide energy and heat as well as clean cooking fuels to get rid of traditional energy sources. Biogas production solves the problem of growing volumes of organic waste, which contributes to the reduction of global greenhouse gas emissions.

1. Introduction

Renewable energy is the undisputed trend of the twenty-first century. In many countries, especially in those located in the European region, an intensive decarburization process is underway, this is primarily associated with the environmental factor and the factor of depletion of hydrocarbon energy sources. We also note that most countries in the world are importers, not exporters of energy resources, for example, let's take oil, thus their energy and economic security in general is also under threat, which accordingly leads to the issue of decarburization of all sectors of the economy. As of September 2020, 2/3 of the electricity generated in the European Region does not contain hydrocarbon emissions.

The world has been facing the threat of an energy crisis for a long time. At the moment, the share of hydrocarbon resources (oil, gas, coal) in the world fuel and energy balance (FEB) is about 80%, the share of biomass, in turn, is about 10%. Of course, in the coming decades, we are unlikely to begin to experience a shortage of oil products, natural gas and other hydrocarbon energy sources, but we need to think about the future now and in order to avoid a global energy crisis that will destroy the world economy to its full extent, it is necessary to pay attention and build up our potential power generation capacities from renewable energy sources.

As for the technological component, this is the process of energy production using environmentally friendly and at the same time renewable natural resources, for example: wind, sun, various types of waste and biofuels in general, etc. Let us analyze each type of renewable energy resources separately [1-2]:
Wind power. Energy is generated by using the kinetic energy of the wind flow, the turbine is set in motion and electricity is generated. Wind flow is the main resource of wind energy. Wind turbines of modern designs make it possible to use wind energy cost-effectively. With the help of wind generators today, it is possible not only to supply electricity to the "grid", but also to solve the problems of power supply to local or island objects of any capacity.

Solar energy. Solar radiation is the main resource in this type of energy. The source of energy for solar radiation is thermonuclear reactions that take place on the Sun.

Biofuels. In simple terms, this is a fuel that is obtained by processing biomass in various ways (biological - by means of bacteria, or thermo chemical). Biomass is currently the third most popular renewable energy source, second only to solar and wind energy. However, the potential of biofuel energy is enormous, which in the near future may make it possible to bring it to the first place in popularity among renewable energy sources.

2. Materials and methods

On the graph (figure 1), we can notice that the trend of growth in the production capacity of renewable energy continues from year to year and the prospects for stagnation or recession of this course are not expected. Production capacity growth in 2009-2019 amounted to 2168.8 TW / h (an increase of 341%). The average annual growth was about 16%. The most successful and breakthrough indicators were given by the Asia-Pacific region (40.9% of the total), mainly due to the development of alternative energy in the People's Republic of China. The worst indicators of RES development belong to the countries of the CIS region, they accounted for about 0.1% of the total RES production capacity by 2019. In general, not a single region has shown negative indicators over the past couple of years, which may have a positive effect on the potential forecast for the development of alternative energy around the world in the near future. In our opinion, given the new laws on decarbonization in the economy in the European region, we should expect a sharp surge in production capacity in this region, which may well be at the level of 10-14% per year [3-7]. The progressive energy legislation of California and a number of other US states is also aimed at ousting hydrocarbon fuels, including nuclear energy, from the energy market in their states, which will also lead to a surge in the development and introduction of green energy in all sectors of the economy. In 2018, the state of California signed SB 100, which increased its environmental requirements and requires that all of the state's electricity be generated without the aid of hydrocarbon resources by 2045.

![Figure 1. Dynamics of the total installed capacity of RES production.](image-url)
3. Results and Discussion

Bioenergy is considered one of the most promising types of renewable energy sources in the Russian Federation today. Biogas production is considered an increasingly interesting segment for investments. Biogas is the general name for a combustible gas mixture obtained from the decomposition of organic substances as a result of an anaerobic microbiological process (methane fermentation). The efficiency of biogas depends on the environment in which it decomposed; therefore, favorable conditions for the life of bacteria in the absence of oxygen are necessary.

Since biogas consists of 2/3 of methane (figure 2) - a combustible gas that forms the basis of natural gas, and has a specific calorific value of 60-70% of its energy value [1-2]:

- 7000 kcal per m$^3$ of natural gas;
- 1 m$^3$ of biogas is equivalent to 1.5-2.2 kWh of electricity;
- 2.8-4.1 kWh of heat;
- 1 liter of diesel fuel.

![Composition of Biogas](image)

This allows biogas to be used as an energy source in engines, gas water heaters and heating systems. Biogas plants play the role of treatment facilities, which allows solving the issue of waste disposal. Thus, there are 44 digester tanks at the Kuryanovsk and Lyubertsy treatment facilities, the total biogas production capacity is approximately 280 thousand m$^3$.

Currently, a large amount of organic waste is produced, which can be used for the production of biogas, as a clean source of energy, which has many potential in economic and environmental development [8-11].

A special bioreactor unit is used for biogas production. It is a complex of structures consisting of various devices designed for the preparation and storage of raw materials, the production of biogas itself, as well as its collection and purification. The equipment makes it possible to obtain combustible gas directly at the enterprises, to burn it in the boilers of the enterprise to obtain industrial steam or to use it for other needs.

Biogas has technological flexibility: its use makes it possible to generate several types of energy resources at once: electricity, motor fuel, heat and gas.

One of the directions for the development of alternative energy is cogeneration plants, which are capable of producing electric and thermal energy using one type of fuel, which makes it possible to
meet the demand for energy resources. They can be installed at the biogas production site and continuously produce electricity, which will ensure stable operation of the biogas production site.

When processing 1 ton of solid waste, it is possible to obtain from 45 to 100 m³ of biogas, while 1 m³ is equivalent to 1.5-2.2 kWh of electricity, 2.8-4.1 kWh of heat.

The principle of cogeneration plants is as follows: a gas piston engine rotates an electric generator using the energy of burning biogas, generating electricity in an effect of 55%, and the remaining heat through a system of heat exchangers is 35%.

Cumulative electricity and heat production is an economically viable way to generate electricity. A cogeneration plant operating in a three-shift operation of the enterprise: in the morning, afternoon and evening, it produces electricity and heat, and at night when the enterprise is not functioning, all systems use centralized electricity at cheap night rates. The cumulative effect of such an installation is 90% (figure 3) [1-4].

![Figure 3. Total production of heat and electricity.](image)

To understand the efficiency, one can compare the efficiency for separate production of electricity and heat with the total production.

For example, in case of separate production, the power plant operates with an efficiency of 36% and a boiler house with an efficiency of 80% - the average efficiency will be 58% (figure 4) [1-3].

With cogeneration, the efficiency of the power plant is 55%, but the installation generates heat with an efficiency of 35% - the total efficiency will already be 90%.

The economic benefits of CHP units are worth emphasizing. Their payback period is 2.5-4 years, and their service life exceeds 25 years. The total cost of the generated capacity is 2-2.5 times cheaper than centralized supply.

In Europe, the main sources of biogas production are: food scraps, manure or sludge from the river. The developed countries of the European Union were the first to start switching to other energy sources and supported various initiatives aimed at introducing new technologies in energy production.

In developed countries, the processing of organic waste in biogas plants is more often used for the production of heat and electricity. The energy produced in this way accounts for 3-4% of all energy consumed in European countries [12-14].

Europe, China and the United States account for about 90% of world production. Germany is the sales and production leader for two-thirds of the European biogas plant capacity.

One of the world's largest biogas parks is located in the federal state of Mecklenburg-Pomerania on the outskirts of the small town of Güstrow. The construction of the NawaroBio-EnergieParkGüstrow park started in 2009, and already in 2010 the park started operating at full capacity. The amount of
investment amounted to 100 million euros, the number of employees at the commissioned facility - 100 people.

The area of this park is 20 hectares, there are 5 modules, 20 enzymes and 20 containers for fermentation products for 5 thousand tons each.

The annual biogas capacity of such a park is 46 million cubic meters. This is enough to produce 160 million kWh of electricity or 180 million kWh of heat per year.

This amount of energy is enough to supply 50 thousand households, i.e. small town.

Other countries such as Denmark, France, Italy and the Netherlands are actively promoting biogas production.

In China, policies support the installation of boilers in rural areas to increase access to modern energy and clean fuel for cooking; these digesters account for about 70% of the biogas capacity. Various programs have been announced to support the installation of larger cogeneration units.

In the United States, the main route for biogas production is landfill gas collection. There is also growing interest in biogas production from agricultural waste, as domestic livestock markets are responsible for nearly a third of US methane emissions.

About half of the remaining production comes from developing countries in Asia, in particular Thailand and India.

Biogas production produces a wide range of expensive and important products, such as electricity, fertilizer or heat, which can be used in an environmentally friendly manner.

Biogas in Russia can become the main source of energy, replacing low-efficiency and environmentally friendly fuels. BSUs have great potential in the vastness of the country. Also, the installations are distinguished by reliability, efficiency and environmental friendliness. Russia has a rich resource base. The availability of raw materials determines the territorial flexibility: for a number of enterprises, biogas production is an economically profitable solution: biogas plants can be located on the territory of the enterprise, do not require the construction of an expensive gas pipeline.

It is also possible to identify the existing prerequisites for the development of the market in Russia:

- Increase in electricity tariffs;
- Depletion of oil and gas reserves;
- The presence of settlements that do not have gas supply and constant electricity supply.

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**Figure 4.** Separate production of heat and electricity.
Against the background of renewable energy sources, biogas has a number of advantages. If we compare biogas with other renewable energy sources, for example solar or wind energy, then biogas has an important feature - constant production and maximum use of sustainable power. The sufficiency of raw materials for biogas production contributes to low purchase and transport prices, which are part of the operating cost structure.

Biogas is the cleanest fuel and its energy use is CO\(_2\)-neutral, since the carbon monoxide emitted is within the natural carbon cycle. Thus, the concentration of CO\(_2\) in the atmosphere does not increase compared to the use of solid fuels. Biogas production reduces soil and water pollution. Overcrowded landfills allow toxic fluids to drain into underground water sources. Biogas production can improve the quality of eastern waters and reduce the incidence of water-borne diseases. Likewise, waste collection and disposal are significantly improved in areas with biogas plants. This, in turn, leads to improved environmental health, sanitation and hygiene. Biogas production helps to reduce dependence on the use of fossil fuels such as oil and coal.

In addition, biogas production increases employment in rural areas, an increase in real incomes of the population, and develops the energy infrastructure of a village or district.

The main result of the development of the biofuel, biogas energy sector is the improvement of the ecological situation on our planet, due to the fact that biogas will gradually be able to displace natural gas, especially coal, from those sectors of the economy where they are currently quite strong. The modernization of water treatment plants and the installation of anaerobic structures will provide water treatment plants with constant energy, which will prevent the malfunction of the enterprise and subsequent environmental problems (an important factor in megacities).

The next result of the development of biogas energy will be the restructuring of the world fuel and energy balance, which will allow, if not avoid, and then delay the global energy crisis. The time gained should be spent on the subsequent restructuring of the world fuel and energy balance. The European region and a number of US states in the next decade can become experts in the field of decarbonization, which will allow Russia and other countries to restructure their fuel and energy balance more effectively, with the least losses, both in time and in finance [1-3; 13-14].

Development of agricultural regions. At the moment, in Russia, as in a large number of countries of the world, there is a problem in the field of agriculture. It is associated with very high costs for equipment, machinery, and, first of all, with the purchase of very expensive and sometimes even scarce fuel. All this inhibits the development of agricultural regions, increases the unemployment rate in the regions, lowers the competitiveness of domestic agricultural enterprises and, in general, the growth of the GDP level. Efficient use of waste, namely processing from biofuels, biogas, would increase employment in this sector of the economy, increase the productivity of this sector. Large farms, in the event of a surplus of biogas, after meeting their own energy needs, can send it for export (to other farms, nearby cities, regions, possibly even countries). Thus, it will save money and perhaps fill the budget of farms, which will allow them to develop, expand and benefit their country.

Energy security. The countries that are importers of hydrocarbon resources at the moment are volatile, therefore they are subject to manipulation and have a share of energy risk. Biogas can allow restructuring the fuel and energy resources of these countries and, accordingly, create a decarbonizes economy, which is a safe option for the importing countries for the development of the country's economy, an example is China, which does not have large reserves of energy resources, apart from coal. However, he is a leader in the field of alternative energy. However, of course, the structure of China's fuel and energy balance is dominated by hydrocarbon energy sources that it imports, thus this country is energy dependent and sensitive to a potential energy crisis.

4. Conclusion
As mentioned at the beginning, the potential of biogas has endless possibilities and it is likely that in the near future it can become, if not the leader of the entire energy sector, then the green energy sector for sure. Now, the world biogas market is estimated at US $ 27 million, it is expected that by 2027 the growth of the biogas market will be about 67% and will be equal to US $ 45 million. Further average
annual market growth will be about 6-8%. One of the fundamental factors of such growth will be the active use of the raw material segment of urban wastewater. Every year in Russia and in the world, the level of urbanization of cities in different regions is growing; in Russia, the level of urbanization is 75%, which results in an increase in the volume of wastewater. In the Moscow region, the Kuryanovsk and Lyubertsy water treatment facilities are equipped with anaerobic plants. On average, water treatment plants produce about 130-140 thousand cubic meters of gas per day, and can produce at least 90 million cubic meters of gas per year. It should also be borne in mind that this is far from all the water treatment facilities in the Moscow region equipped with anaerobic plants. It is worth noting that these structures work in tandem with mini-thermal power plants, which allows reducing the load on the city's power system, as well as directing the released capacity to provide various urban development facilities. If we take the environmental factor, then the installation of anaerobic equipment and the generation of subsequent electricity with the help of biogas at mini-thermal power plants made it possible to reduce emissions into the atmosphere of Moscow by 6,500 tons.

Every year, the volume of electricity production is growing, and the fuel sources for generating EE dry up (gas, coal), which makes us pay attention to alternative energy, in particular to biogas. The main advantage of this type of fuel over wind and solar energy is the possibility of production, both in urban and rural environments, as well as in a complete solution to the problem of utilization of urban and rural waste, which puts the efficiency of biogas in priority over wind and solar energy.

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