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Analysing the use of biofuels in agriculture

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Abstract. This paper poses the problem of fuel energy and ecology in Russia. The paper discusses in detail the operation of biogas production plants. Advantages and disadvantages of such production, material costs, and raw material costs are presented. The statistics of biofuel production in the countries of the world is visualised. The paper compares different types of propulsion systems using different fuels, identifies the advantages and disadvantages, and examines the operation of one of the largest biogas plants in the world.

1 Introduction

At the end of summer, regions across Russia began to report that petrol and diesel fuel was missing from petrol stations. The situation is worst for agricultural producers, for whom the fuel shortage occurred during the harvesting campaign and sowing winter crops. Due to a multiple increase in wholesale prices, independent petrol stations are forced to sharply increase the cost of fuel at retail or close down, while petrol tankers cross half the country in search of full oil depots.

A related problem in the energy sector is the issue of environmental management and ecology. A large number of projects for the protection of rare species and nature reserves are being implemented in Russia, so it is also important, along with the industrial development of the state, to preserve the environmental safety of the state's territories in the process of fuel production and exploitation [1–6].

"In Russia, environmental issues and rational use of natural resources are rightfully among the most important national priorities. Programmes aimed at protecting rare animal species are being implemented, and large-scale research, information, educational and creative projects are being implemented," commented Vladimir Putin.

The President instructed the government, together with oil companies, to develop a plan to stabilise petrol and diesel fuel prices, and to provide domestic agricultural producers with sufficient fuel [7].

Is it possible to solve this problem in the field of agriculture, because the country's GDP is highly dependent on this segment, which may further affect the economy of the state?

Let us consider a promising industry for today, i.e. biofuel energy.

Biofuel is a vivid example of practical implementation of new technologies in the field of energy. This is a fuel derived from biological matter (a product of processing manure, dung and other organic waste), as well as a good alternative to other types of fuel [8–10].

Biofuels production worldwide is set to rise sharply over the next decade owing to significant public investment, according to a report published by the Organisation for Economic Co-operation and Development and the UN Organisation for Food and Agriculture.

The problem of fuel shortage in agriculture can be solved by active introduction and development of stations for processing organic waste into biofuel. Such fuel is already used in a number of countries and is actively used in power plants of various spheres of industrial and transport industries.

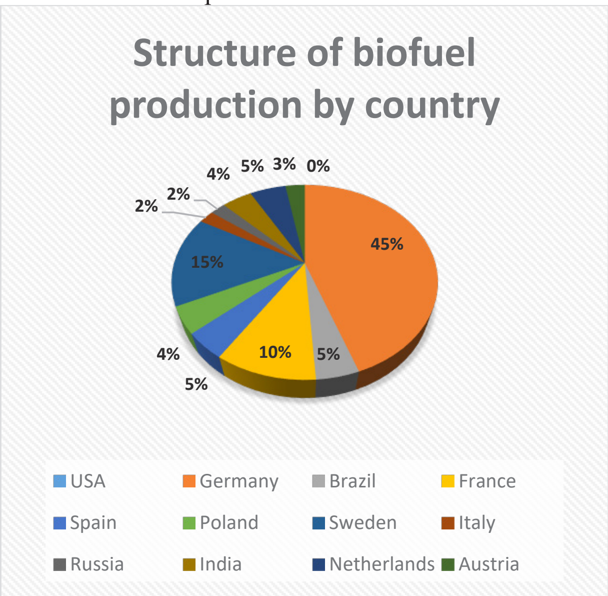

Fig. 1. Structure of biofuel production by country.

There are only 4 of them in Russia today: two in the Belgorod region, one in the Vladimir region and one in the Kaluga region [11].

About 90 per cent of biofuel production capacity is in the US, Brazil and the EU. In Brazil, 90 per cent of

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produced cars have engines designed to run on ethanol. 3 million cars run on ethanol alone and another 16 million on a mixture of ethanol and petrol.

In the U.S., 12% of vehicles run or can run on alternative fuels, including ethanol.

Europe has about 7.8 GW of biogas-fuelled capacity, China possesses about 5.5 GW, and the US has about 2 GW. "The big global oil and gas companies have started to get into this business. This is how they get carbon credits for generating clean energy and reduce carbon taxes on their core business," Georgy Apkaneyev, a chief expert at Rusatom Services, comments. In Russia, there are only 20 MW of such capacities so far [12, 13].

2 The main part

Let us consider the main advantages of biofuels in the agrarian sphere, get acquainted with the process of production, cost of such fuel, productivity and places of application, and summarise the prospects of introduction of fuel from organic waste in large volumes [14].

For the agricultural sector, the utilisation of organic waste is very costly. For example, keeping 200 tonnes of chicken manure in composts, for further fermentation and use only as organic fertiliser, includes storage facilities, staff, utility bills, machinery and other indirect costs. At the same time, waste-to-biogas plants can use this volume as feedstock, while the process will also produce organic fertiliser. The costs of maintaining composts are not excluded, but are now more likely to pay for themselves.

Table 1. Amount of biomass and biogas from feedstock.

Feedstock for biogas	Amount of biomass	Quantity of biogas
Liquid manure (cattle)	1 m^3	20 m^3
Liquid manure (pigs)	1 m^3	30 m^3
Poultry droppings	1 m^3	40 m^3
Sewage sludge	1 m^3	5 m^3
Biowaste	1 tonne	100 m^3
Waste fats	1 tonne	650 m^3
Grass	1 tonne	125 m^3

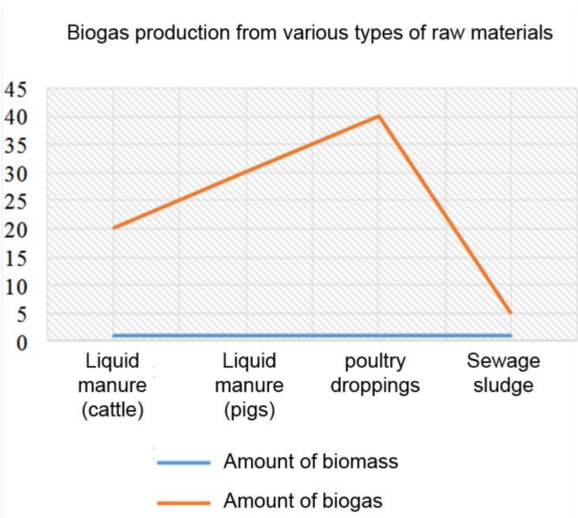

Fig. 2. Biogas production from different feedstocks.

Let us compare the calorific value of biogas with other fuels.

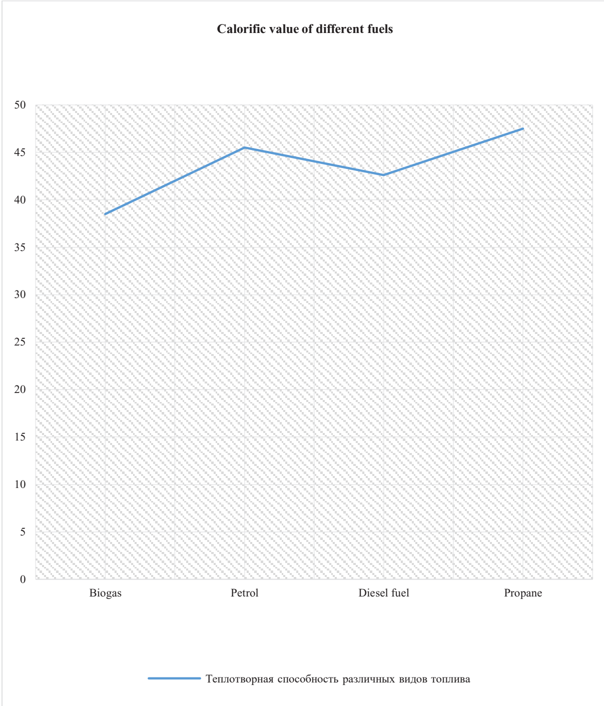

Fig. 3. Calorific value of different fuels.

Table 2. Calorific values of fuels.

Fuel	Calorific value
Biogas	38.5
Petrol	45.5
Diesel fuel	42.6
Propane	47.5
Coal	29.3

The table shows that the calorific value of biogas can compete with other fuels.

Other benefits of biofuels include:

1. Reduction of carbon dioxide emissions through natural methane decomposition.
2. Reclamation of valuable land areas normally used for organic wastewater treatment.
3. Elimination of odour and contamination that accompanies the decomposition of organic material.

Let's look at the biogas production process in detail to see exactly what useful products can be obtained from the processing.

Waste collection and preparation involve:

1. The process of fuel formation based on chemical and physical transformations.
2. Manure, like droppings, as not only animal excrement but also a very complex substance. It is filled with various microorganisms that are involved in such transformations.

While in the intestines, animals process food, break down complex organic chains, transforming them into simple substances suitable for digestion through the intestinal walls. The number and activity of microorganisms are adjusted by gastric juice and substances secreted by the intestine. During the digestion of manure and other organic waste, anaerobic bacteria produce biogas. It consists of carbon dioxide, methane and impurities (nitrogen, silicon, hydrogen sulphide).

3. The excreta collected in the manure collector containing many large fragments. It is therefore shredded using any suitable shredders. Often this function is performed by a pump that transfers the material to the bioreactor. Energy content of the used substrates, renewable feedstocks provide about 81% of the energy in agricultural biogas plants. About 19% of the energy supply comes from the use of manure.

Bioreactor loading and maintenance consist in the following [15].

The substrate is filtered and, if necessary, filled with green mass. Then it is pumped into a tank located near the bioreactor. In this tank, the ready-to-use solution is heated to the required temperature and after filling is poured into the bioreactor, which is surrounded on all sides by a water jacket. This method of heating ensures the same temperature in all layers of the contents, and part of the produced gas is used to heat the coolant (water). During the first loadings, the coolant will have to be heated due to third-party energy sources. However, other ways of heating the contents are also possible [16].

Drainage and waste disposal are implemented as follows.

1. The gas produced by the bacteria accumulates at the top of the reactor, resulting in a slight positive pressure. The gas is withdrawn to the gasholder either periodically as it reaches a certain pressure or continuously, but in this case the amount of withdrawn gas is controlled to maintain the required pressure.

2. Completely decomposed material, due to its higher density, settles to the bottom of the reactor; a layer of waste liquid appears between it and the most active bed. This is therefore removed before mixing, together with part of the sludge, which are then separated. Both types of waste are strong natural fertilisers: the liquid accelerates plant development, and the sludge improves soil structure/quality and contains humic substances. Both types of waste can therefore be sold and also used on your own fields. If the waste is not to be separated immediately into fractions, it should be stirred periodically to prevent the sludge from sticking together. Otherwise, it will be difficult to remove when emptying the tank [17–19].

Gas purification is carried out in the following way.

1. In order to use biogas as fuel for internal combustion engines, it is necessary to pre-clean the gas from water, hydrogen sulphide and carbon dioxide.

2. Several technical solutions are used to purify biogas, each of which is aimed at removing a specific substance from its composition. Water is removed by condensation, for which the product is first heated and then passed through a cold pipe, on the walls of which water droplets settle. Hydrogen sulphide and carbon dioxide are removed with the help of sorbents at high pressure. A properly constructed purification line raises the methane content to 93-98%, which turns biogas into a very efficient fuel that can compete with other gaseous fuels [20].

Biofuels can be used everywhere instead of the usual fuel (petrol, diesel fuel) and also instead of electricity. Biogas is mainly used in analogues of diesel power plants.

We consider the MWM TCG 3016 V12 and BAUDOUIN 12M33G1400/5 engines:

Fig. 4. MWM TCG 3016 V12.

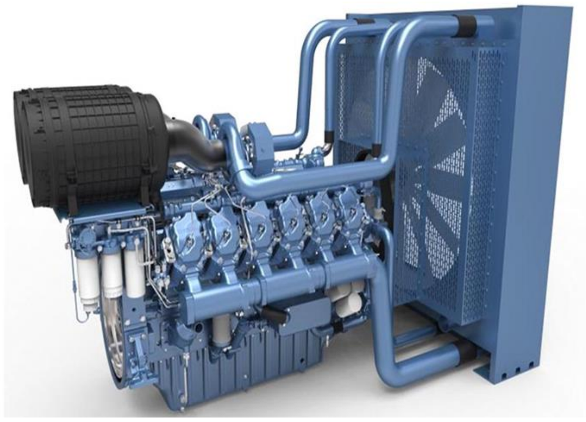

Fig. 5. BAUDOUIN 12M33G1400/5.

The main difference between these energy plants is the type of used fuel, the MWM plant uses biogas and the BAUDOUIN plant uses diesel.

Table 3. Comparison of the technical characteristics of the engines.

Characterisation	MWM TCG 3016 V12	BAUDOUIN 12M33G1400/5
Number of cylinders	12	
Cylinder arrangement	V-shaped	
Rotational speed	1800	1500
Power	680 kW	880 kW
Efficiency	42.5	43
Fuel consumption	143 nm^3/h	259 l/h
Oil consumption	<0.1 g/kWh	~0.3 g/kWh

The table shows that the diesel engine develops more power, but let us pay attention to the speed and efficiency. The speed of the biogas-fuelled plant is higher than that of the diesel-fuelled plant and the efficiency is comparable. Also, in the particular case of comparison, the MWM plant can operate not only on biogas, but also on diesel, on electricity, on petrol, which also affects the individual characteristics of the engine. But even taking this factor into account, the plant is competitive with the diesel engine and in some aspects even performs better [21].

It can be concluded that by using gas fuels, and the corresponding power plants, we will not lose in performance and will gain in many aspects in terms of costs.

Let us consider the operation of a biofuel plant by a concrete example:

The world's largest biogas park is located on the outskirts of Gustrow, Germany. A construction of this park, called Nawsro Bio-Engine Park Gustrow, started in 2009, and a year and a half later, in 2010, the park reached full capacity. The investment totalled €100 million and the number of employees was 100.

The name of the park contains the name of the developer and subcontractor company, who carried out full control of all works: NAWARO BioEngine AG [22].

This park occupies an area of 20 hectares, on which 5 modules, 20 fermenters and 20 tanks for fermentation products (5 thousand tonnes each) are located, as well as buildings, a biomass preparation site, wastewater from which flows to the fermenters, and a compressor network for gas supply.

The annual capacity of such fleet is 46 million cubic metres of gas (10000 cu.m./h). This is 160 million KWh or 180 million KWh per year.

The raw materials used here are maize, cereals, cut grass and silage. A total of 450,000 tonnes of raw materials are needed per year [23].

The remaining fermentation products are dried and pressed. In total, up to 85,000 tonnes of pressed fertiliser and 90,000 tonnes of liquid fertiliser are produced.

This station also provides up to 5,000 cubic metres per hour of natural gas to the network in the region.

Fig. 6. Nawaro Bio-Engine Park Gustrow.

3 Conclusion

1. The use of agricultural and other organic waste as biofuel allows for a closed cycle of agricultural production. The residue from anaerobic digestion is odourless and can be transported to the fields as fertiliser. This type of fertiliser is immediately absorbed by plants without contaminating soil or groundwater.

2. In the light of regular energy crises, energy production from biogas is considered a promising renewable energy source. Biogas plants convert solar energy stored by plants into biogas through a biodegradation process. This process is neutral with respect to the CO balance, as only the amount of carbon dioxide previously absorbed by plants during photosynthesis is released into the atmosphere.

3. Generating electricity and heat in biogas plants is a promising technology that helps humanity become independent of limited fossil fuel reserves and also protects the environment.

4. The profitability of the project on implementation of biogas plants is undoubted, because in the process of fuel production we receive, in addition to the biogas itself, separate fertilisers, which contributes to maintaining positive dynamics in the issue of ecology. In addition to the positive impact of fertilisers, it should be noted that the production of biofuels will not threaten the ecology in the country.

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