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Methodical Framework of the Support and Decision-making System for the Collection and Disposal of Organic Raw Materials

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Abstract

Topical and important issue is the national problem of introduction of biomethane production and the Ukrainian gas transportation system. This problem can be addressed through the use of information technology based on the monitoring and forecasting the prospective base of knowledge organic raw materials and optimal scheduling of seeding, harvesting and conversion of crops and other organic waste into biogas energy. Based on the analysis of problems of management and factors affecting the efficiency of the biogas complexes (BGC) functional structure of decision support systems that is best adapted to the challenges of planning for the organization cultivation, collection and processing of organic raw materials into biomethane has been developed.

Keywords: biomethane; support and decision-making system; organic materials; biogas; energy crops.

1. Problem

Currently, topical and important issue is the national problem of introduction of biomethane production and the Ukrainian gas transportation system. At the same time for biomethane production, biomass from large farms and energy crops (EC) from the farmland can be used. According to experts [1], the available waste only could produce up to 3.2 billion of cubic meters of biomethane per year. If one million hectares free agricultural land is used for under energy crops, we will be able to receive an additional 3.3 billion of cubic meters of biomethane per year which is a total of 6.5 billion of cubic meters annually. One of the directions of solving this problem is the widespread use of information technology which can monitor the existing base of organic raw materials and forecast the prospective one for its processing into biogas complexes (BGC) to get maximum volume biomethane.

2. Analysis of research and publications

Many works are devoted to forecasting output efficiency of biogas from organic materials (OM). The papers [2–4] describe the current technical level of biogas technology. It is shown that the level of implementation of these technologies remains unsatisfactory. In [5] a review of the use of modern information technologies in agricultural management around the world is given. Examples of remote sensing and geographic information systems for agriculture are provided, the creation of agrarian resources monitoring system and forecasting yields crops in Ukraine is discussed.

Depending on the method of placing recording devices, methods of remote sensing include the ground, aviation and space sensing, but they have one thing in common: information is obtained by recording electromagnetic radiation reflected or emitted from the earth's surface.

In [6], the methodological framework for the use of precision farming system, which consists the following stages, is provided: 1) development of an electronic map of the entire economy; 2) samples of the soil to a depth of 30

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centimeters; 3) planned fertilization based on coordinates obtained earlier; 4) yields mapping. This system is based on the use of modern information technology.

Based on the results of the analysis of scientific papers, the issues of development and use of decision support system (DSS) for the organization of growing, collection and transformation of organic material into biogas not adequately addressed currently.

The purpose of the article is to develop a functional structure for the organization of organic material growing, collection and processing of into biogas planning.

3. Basic materials research

Biomethane – a biogas (60 % methane and 40 % CO_2), purified to natural gas quality. In different countries, the requirements for methane concentration are in the range from 95 % to a maximum of 98 %. Western countries already use the technology, through which the separation of CO_2 from methane content is ensured and the latter is brought to 95–98 % for submission to the gas pipelines. In Ukraine, these technologies have great prospects tbecause the country has well developed gas distribution network to which BGC can be connected. It is necessary to establish a system for recording biomethane supply into the gas network with BGC.

Typically, BGC is tied to sources of raw materials - large farms in the countryside or to farmland where energy crops are grown. Now the practice is rarely to use manure exclusively. Most of the settings for his work uses silage, grain residues, and sometimes operate without manure.

The most important task for planning energy crops with the help of DSS is to place various sowing energy crops in the area considering the geophysical characteristics of each culture.

In terms of gas output substrates with a high concentration of energy give the best result: beets, potatoes, corn waste. Output of methane derived from these crops can reach 350–380 liters/kg organic dry substrate. In addition, there is a group of organic raw materials, which includes fresh grass, foliage beet, corn and grain plants, out of which methane totals 270 to 330 liters / kg of organic dry substrate. The smallest gas output below 200 liters/kg of organic dry substrate is provided by straw [7]. Silage corn is by far the most important crop for use in biogas plants. Corn is also called C4 plants because of the large output of dry weight. Technology, which is necessary for the processing of the culture, is usually always available in the workplace. Corn is easily stored and even when used in pure form, does not cause disturbances in the process of biogas plants. Today there are special varieties of corn for use in biogas plants.

Readiness of the crop for siloing and getting the maximum volume of biomethane is optimum time for collection. Typically, during harvesting, corn should have dry matter content of 28–35 % and in a state between milk ripeness and suitability for flour. In favorable areas for cultivation, different varieties can produce more than 8000 m^3 of methane from one hectare of biomass grown. Output of silage corn crop varies between 120 and 270 quintals/hectare, gas output- between 300 and 380 liters per kg of organic dry matter [7].

To create optimal, in terms of crop rotation energy, biomass for BGC, it is necessary using DSS to reconcile the three main factors and do the following:

1) the choice of varieties and sequence of cultivation of high yield of each class of organic dry mass per hectare per year;

2) choosing varieties based on high specific output for each class of methane and best compatibility nutrients in their mixing;

3) optimization of the constituents, based on the maximum potential methane among different cultures (e.g. by improving the fat content through the integration of oil crops).

For optimum in terms of energy, crop rotation, we use a combination of the best groups of plants C3 and C4. Plants C3 group better survive cold winter, while the rich in biomass heat-loving plants C4 group better survive summer. This makes it possible to double the crop during the year with a total capacity of about 250–300 quintals of dry mass per hectare. After early collection of the first harvest, many weeds cannot grow, helping to renounce the use of herbicides. Already existing weeds even help increase output of dry matter. This combination helps crops enables us to get dry matter yield of 250 quintals/ha and even in bad conditions with sufficient rainfall has an advantage over corn. Winter crops are the best crops for the first harvest.

BGC economic effect depends largely on the cost of production of the substrate, its quality, and cost for processing OM. Therefore, the company that operates the BGC should carefully check the quality and purchased on the market or feasibility substrate cost-effective biomass cultivation on their lands. The primary raw material for BGC may be corn. This culture gives a high energy output and its conservation is relatively simple, given the long experience. Wider crop rotation could be appropriate from an economic and technological standpoint. Relatively sufficient number of compost is recommended to extend the range of crops for biogas subsidiary plants.

Let us consider solving this problem in this sample. Let us assume that is predicted to grow corn and sugar beet on the area of 200 hectares under sugar beet relegating no less than 50 hectares for BGC.

Techno-economic performance of growing these crops is listed in the table:

Table 1

№	Technical and economic indicators of per 1 ha	Agricultural crops		Available resources
		Corn	Sugar beets	
1	Manual labor, man-days	5	25	270
2	Mechanized labor, man-days	2	8	80
3	Profit, thousand UAH.	0.7	1	

Optimality criterion for the process of growing, harvesting and processing OM is to maximize profits (Z) by increasing the production and sale of methane gas.

Economic-mathematical model of the production of corn and sugar beet is:

$$Z = 0,7x_1 + x_2 \rightarrow \max, \tag{1}$$

under conditions

$$x_1 + x_2 \le 200\,; \tag{2}$$

$$5x_1 + 25x_2 \le 270\,; \tag{3}$$

$$2x_1 + 8x_2 \le 80\,; \tag{4}$$

$$x_2 \ge 50\,; \tag{5}$$

$$x_1 \ge 0,\ x_2 \ge 0\,, \tag{6}$$

where x_1 – the required acreage of winter wheat; x_2 – the required acreage of sugar beet.

This problem is solved using linear programming methods [8]. While the estimated costs for the supply of substrate to BGC with the example of corn have the following structure:

Growing – 50 %.

Harvesting – 15 %.

Transportation to the silage – 15 %.

Fixed and variable costs of silage – 13 %.

Download the substrate in the fermenter – 7 %.

Because in corn dry matter content is relatively small while water content is large, in this case transportation costs are disproportionately large. Thus, the cost of supply of maize is increased by 250-350 USD/hectare while transport distances is increasing from 2 to 20 km [9]. It leads to increased costs up to 25% and therefore impairs economic efficiency of BGC.

In this regard, using the DSS has practiced new combined methods of collecting and transporting OM using trucks to reduce the cost of delivery. This is inevitably linked to the performance of large-scale works in transportation of biomass to BGC and export of organic fertilizer on fields. Therefore, the need for coordination of organic raw materials harvesting and transportation, using DSS, increases. The success depends on timely planning of distribution areas for planting crops, harvesting and transportation of the substrate and removal of organic fertilizers. During harvesting (especially corn), the most efficient is one-step method in which the transport unit is loaded on the chopper and transporting crushed mass directly to the silage.

Depending on the number of used shredders required number of units of transport and local characteristics required coordination using DSS to collect all works and transport OM. During the OM harvesting, many factors must be taken into account. In addition to traditional means of harmonization (for example mobile phones) in large-scale processes of harvesting, equipment for all collection and processing of organic raw materials is combined in a network using electronic data processing systems, and mobile GIS, DSS that is distributed to facilitate coordination of the whole harvest logistics.

For multivariate analysis of the collection and processing of OM, it is expedient to use mathematical tools based on the theory of fuzzy logic and linguistic variable. This method is a set of related mathematical models, algorithms and methods and allows the use of expert linguistic variable to predict the usefulness of different methods of collecting and processing OM, including factors that poured into this process.

To establish a hierarchy of factors that affect the process of OM collection and recycling, there is a need for classification by the following criteria: type of raw material, the amount of raw materials, the collection area, the distance from the bioreactor, the method of collection, availability technology to collect necessary load BGC.

Block diagram of DSS for organizing the collection and processing of OM is shown in Fig. 1.

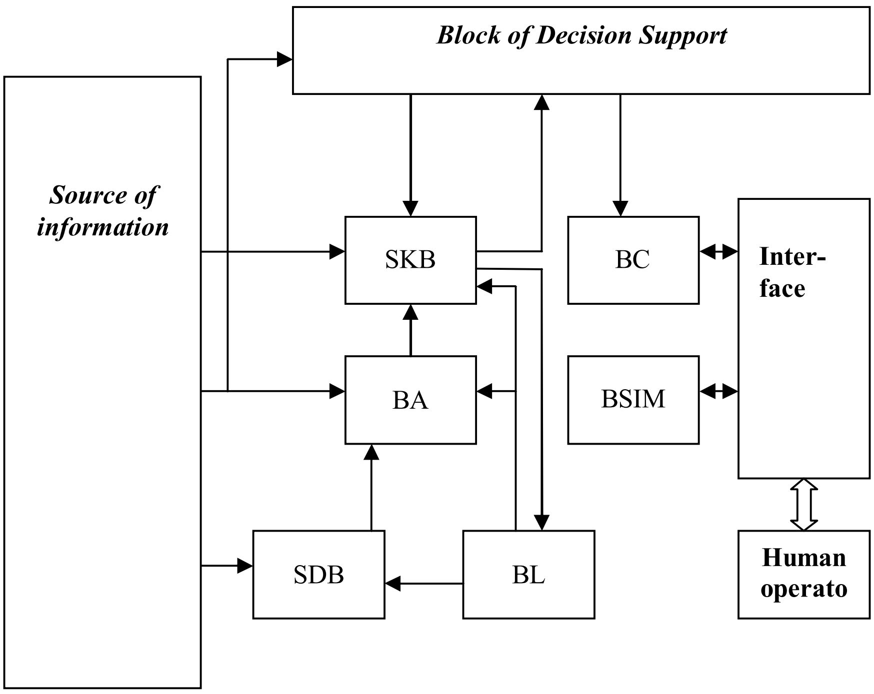

Fig. 1. Block diagram DSS: SDB – situational database, SKB – specialized knowledge base, BA – block of analysis, BL – block of learning, BC – block of comments, BSIM – block synthesis information model

Because formal knowledge of experts in the initial stages of DSS application are not complete and correct then situational database (SDB) and specialized knowledge base (SKB) are improved during the operation. Models of knowledge are constantly adjusted based on objective information on the accuracy of decisions.

The central element of the DSS is a specialized knowledge base through which a mathematical model of the collection and processing of OM, and set the relationship between input variables (parameters telemetry data) and output variables (identified in the technological process (TP) on OM transformation into biogas) is developed. The mathematical model is based on fuzzy knowledge base, which is a set of rules "IF-ELSE" that bind linguistic evaluation parameters and initial assessment of the TP types of OM.

The adequacy of the model to experimental data is determined by the quality of membership functions, through which linguistic evaluation turns into quantitative form. Since the membership function is determined by expert adequacy of fuzzy KB is entirely dependent on the skills of the experts.

All possible basic operation processes can be summarized as follows:

1. Seeding and planned collection of biomass grown specifically for reasonably defined areas.
2. Constant monitoring of the system and lots of additional OM.
3. Determining the type, quantity and quality of the OM.
4. Preliminary calculations of the potential trade volume of biogas (methane), which can be obtained using this OM.
5. Preliminary calculations of costs for planting, cultivation, harvesting and transportation of the OM, as well as export of BGC organic fertilizers to the fields.
6. Determination of the annual workload of bioreactors BGC and profitability.

Thus, in a complex dynamic environment, characterized by constant uncertainty and variability of many factors, the basis for successful BGC operation is the optimal decision-making using the proposed DSS on the organization of cultivation, harvesting and processing of the OM to maximize the volume of biomethane.

4. Conclusions

Based on the analysis of problems of management and factors affecting the efficiency of the BGC ,functional structure of decision support systems that is best adapted to the challenges of planning for the organization of cultivation, collection and processing of organic raw materials into biomethane for further supply to distributed gas transportation system has been developed.

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Методичні засади побудови системи підтримки та прийняття рішень щодо організації збору та утилізації органічної сировини

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Анотація

Актуальною та важливою загальнодержавною проблемою є видобуток та введення біометану до Української газотранспортної системи. Одним із можливих напрямків вирішення цієї проблеми є використання сучасних інформаційних технологій, а саме використання автоматизованих систем, які будуть виконувати моніторинг та прогнозування з створенням перспективної бази знань органічної сировини і оптимального планування засіву, збору та перетворення на біогаз енергетичних культур та інших органічних відходів підприємства. На основі проведеного аналізу задач управлінської діяльності та факторів, що найбільше впливають на ефективність функціонування біогазового комплексу (БГК), розроблена функціональна структура системи підтримки прийняття рішень, яка максимально пристосована до вирішення завдань щодо організації планування вирощування, збору та переробки органічної сировини для виробництва біометану.

Ключові слова: біометан; система підтримки та прийняття рішень; органічна сировина; біогаз; енергетичні культури.