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REGIONAL ENERGY EFFICIENCY MANAGEMENT OF ALTERNATIVE ENERGY SOURCES IN THE CONTEXT OF STRENGTHENING FOOD SECURITY OF REPUBLIC OF BELARUS

Abstract. Development of the circular and green economy, including its individual areas, makes certain adjustments to the national management model, bringing the development of alternative energy sources to the forefront, taking into account the possibilities of their application in specific regions while respecting the effectiveness of commercial activities. The paper presents a comprehensive analysis of the use of fuel and energy resources in agriculture (2000–2020), gives a brief description of the existing installations in terms of energy types. Taking into account the peculiarities of alternative energy sources development (availability of a number of benefits when using alternative energy generation plants; quotas for the size of energy in the context of business entities; lack of recommendations on the establishment and distribution of limits, etc.) methodological provisions are proposed to substantiate the effective consumer of energy from alternative sources, which are based on scientifically sound approaches to assessing energy consumers within quotas, taking into account the importance of their products and with a focus on strengthening food security in conjunction with strengthening the energy security of regions. It has been determined that quotas should be considered as a method of increasing the efficiency of using alternative energy sources, which takes into account the effectiveness of the application of installations, transferred to the final product. The scientific novelty of the development lies in substantiation and development of scientific and theoretical provisions for the management of alternative energy sources at the regional level in relation to agricultural sectors in conjunction with other sectors of the economy, practical implementation of those will contribute to development of solutions agreed between individual economic entities for sustainable development of regions, taking into account formation of optimal levels of use of alternative energy sources.

Keywords: economy, agriculture, energy intensity, efficiency, alternative energy sources, food security, region, management, alternative energy consumer

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УПРАВЛЕНИЕ ЭНЕРГОЭФФЕКТИВНОСТЬЮ АЛЬТЕРНАТИВНЫХ ИСТОЧНИКОВ НА РЕГИОНАЛЬНОМ УРОВНЕ В УСЛОВИЯХ УКРЕПЛЕНИЯ ПРОДОВОЛЬСТВЕННОЙ БЕЗОПАСНОСТИ РЕСПУБЛИКИ БЕЛАРУСЬ

Аннотация. Развитие циркулярной и зеленой экономики, включая ее отдельные направления, вносит определенные коррективы в национальную модель управления, выводя на передовые позиции вопросы освоения альтернативных источников энергии с учетом возможностей их применения в конкретных регионах при соблюдении результативности ведения коммерческой деятельности. В статье представлен комплексный анализ применения топливно-энергетических ресурсов в сельском хозяйстве (2000–2020 гг.), дана краткая характеристика действующим

установкам в разрезе видов энергии. С учетом особенностей развития альтернативных источников энергии (наличие ряда льгот при использовании установок по выработке энергии альтернативных источников; квотирование размеров энергии в разрезе субъектов хозяйствования; отсутствие рекомендаций по установлению и распределению лимитов и др.) предложены методические положения к обоснованию результативного потребителя энергии альтернативных источников, в основу которых положены научные подходы к оценке потребления энергии в секторе экономики в рамках квот с учетом значимости производимой им продукции и с ориентацией на укрепление продовольственной безопасности и энергетической независимости регионов. Установлено, что квотирование следует рассматривать как метод повышения эффективности использования альтернативных источников энергии, в котором учитывается результативность применения установок, перенесенная на конечный продукт. Научная новизна разработки заключается в обосновании и развитии научно-теоретических положений управления альтернативными источниками энергии на региональном уровне применительно к отраслям сельского хозяйства во взаимосвязи с другими секторами экономики, практическая реализация которых будет способствовать выработке согласованных между отдельными субъектами экономики решений по устойчивому развитию регионов с учетом формирования оптимальных уровней использования энергии альтернативных источников.

Ключевые слова: экономика, сельское хозяйство, энергоемкость, эффективность, альтернативные источники энергии, продовольственная безопасность, регион, управление, потребитель энергии альтернативных источников

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Introduction. Strengthening food security in the country (in accordance with the adopted and implemented Doctrine of National Food Security of the Republic of Belarus until 2030) comprehensively affects the areas of improving the efficiency of agricultural production through introduction of resource-saving technologies that reduce material and labor costs, reducing the cost of production. This distinguishes a separate section of fuel and energy resources management in the agri-food sector, taking into account its synchronization with the fuel and energy complex of the country. The current stage of development of the national economy of Belarus is characterized by the instability of the energy market in the position of sufficient resource supply and the country's dependence on one dominant supplier (until 2020, more than 80 % of fuel and energy resources imports were accounted for by the Russian Federation), which brings this problem to the leading positions. It is established that the country's energy policy is aimed, firstly, at ensuring the sustainable development of all sectors of the economy [1, 2]; secondly, at improving energy efficiency, reducing the energy intensity of products and services, as well as increasing their competitiveness [1, 3, 4, 5]; thirdly, at preserving and protecting the environment, including expanding the possibilities of using alternative energy sources [6–11]. Thus, the formation of an effective policy for the management of fuel and energy resources in the Republic of Belarus, in particular in the agricultural sector, the renewal and development of the use of alternative energy sources in all sectors of the national economy determined the importance and relevance of the problem of effective management of alternative energy sources in the context of increasing food security in Belarus.

The purpose of the research is to develop approaches to assessing the preferred consumer of energy from alternative sources in the presence of quotas for its production and use.

Methods. The objects of research are energy of alternative energy sources, installations for generating energy from alternative sources, indicators of production and economic activity of agricultural organizations and other economic entities, administrative districts, regions. The subject of research is theoretical and methodological foundations of alternative energy sources; factors, conditions and patterns of management of fuel and energy resources; results of studies of Belarusian and foreign authors on the problem; regulatory and legal documents in the field of regulation and control of alternative energy sources; organizational-economic relations of agriculture subjects and controls. The main methods are the following: research of normative and legal documents on alternative energy sources[1]; comprehen-

[1] On energy saving: Law of the Republic of Belarus, January 8, 2015, no. 239-Z (as amended by the Law of the Republic of Belarus dated 24.05.2021 no. 111-Z) ; On approval of the Concept of National Security of the Republic of Belarus: Decree of the President of the Republic of Belarus, November 9, 2010, no. 575 (as amended. Decree of the President of the Republic of Belarus no. 49 dated 24.01.2014) ; On approval of Directive № 3 "On priority directions for strengthening the Economic Security of the State": Decree of the President of the Republic of Belarus, June 14, 2007 (as amended by Decree no. 26 dated 26.01.2016) ; On renewable energy sources: Decree of the President of the Republic of Belarus, September 24, 2019, no. 357 ; On the establishment, distribution, release and withdrawal of quotas for the Creation of installations for the use of renewable

sive analysis of regional development processes; structural and dynamic analysis of regional statistics and statistical data of agricultural organizations, etc. Thus, the formation of an effective policy for the management of fuel and energy resources in the Republic of Belarus, and in particular the agro-industrial complex, the actualization and development of areas for the use of alternative energy sources in all areas of the national economy predetermined the significance and relevance of the problem of effective management of energy from alternative sources in the context of strengthening the food security of Belarus.

Results. In the country, for agricultural organizations of the system of the Ministry of Agriculture and Food of the Republic of Belarus for the period 2000–2020, the consumption for the following types of energy resources decreased[2]: diesel fuel – by 1.3 times, from 649 to 511 thousand tons (it accounts for over 50.0 % of spent energy resources, estimated in reference fuel); gasoline – by 4.7 times, from 195 to 41.8 thousand tons; electricity – by 1.8 times, from 1993 to 1093 million kWh with an increase in the gross production of almost all types of agricultural products. For this period in terms of conventional units, the consumption of fuel and energy resources in agriculture decreased by 16.2 %, from 1476 to 1270 thousand tons of conventional units. At the same time, there is no stable dynamics of falling fuel and energy costs for obtaining a unit of production – over the period 2015–2020, the energy intensity of agricultural production decreased by only 5.1 % and in 2020 amounted to 117 USD[3] per 1000 USD of manufactured products, reflecting leaps and bounds. According to our calculations[4], it was found that the costs of fuel and energy resources are predetermined by the technology of crop cultivation, have a different share in the structure of total costs (from 8.1 % – sugar beet to 22.0 % – grain) and vary in the range: – by 40–50 USD/ha; corn for grain – 100–115 USD/ha; sugar beet – 70–100 USD/ha; potatoes – 200–230 USD/ha; rapeseed – 35–45 USD/ha). It was found that in 2020 it took only 1.7 USD/ha (or 4.1 kg of standard fuel) to produce 1 ton of sugar beet, while for the production of rape seeds – 28.3 USD (or 70.4 kg conv. fuel); the production of sugar beet in the estimate of 1000 USD required resources in the amount of 68.9 USD (171 kg of reference fuel), grain – 118.8 USD (295 kg of reference fuel) [12, 13]. Without ignoring the price factor of the market of fuel and energy resources, we note that for the period 2000–2010. the dynamics of prices for fuel and energy resources had a steady progressive growth: from 56.3 % for gasoline to 176 times for electricity; However, the period 2011–2020 the increase in prices was characterized by unstable rates (looking ahead, it should be noted that during 2021, prices for fuel and energy resources changed 30 times); proportional dependence of price changes in the domestic and foreign markets has not been established.

The study of the research results of a number of scientists allows us to state that the use of alternative energy sources in crop production will optimize costs and increase the efficiency of the use of energy resources in cultivation of grain (process: grain drying), potatoes (process: sorting), open ground vegetables (process: sorting), greenhouse vegetables (process: complex of technological operations), etc. [6, 14–24]. At the same time, these sources have not been widely distributed and used due to the specific regulatory and legal, organizational and economic environment that has been formed.

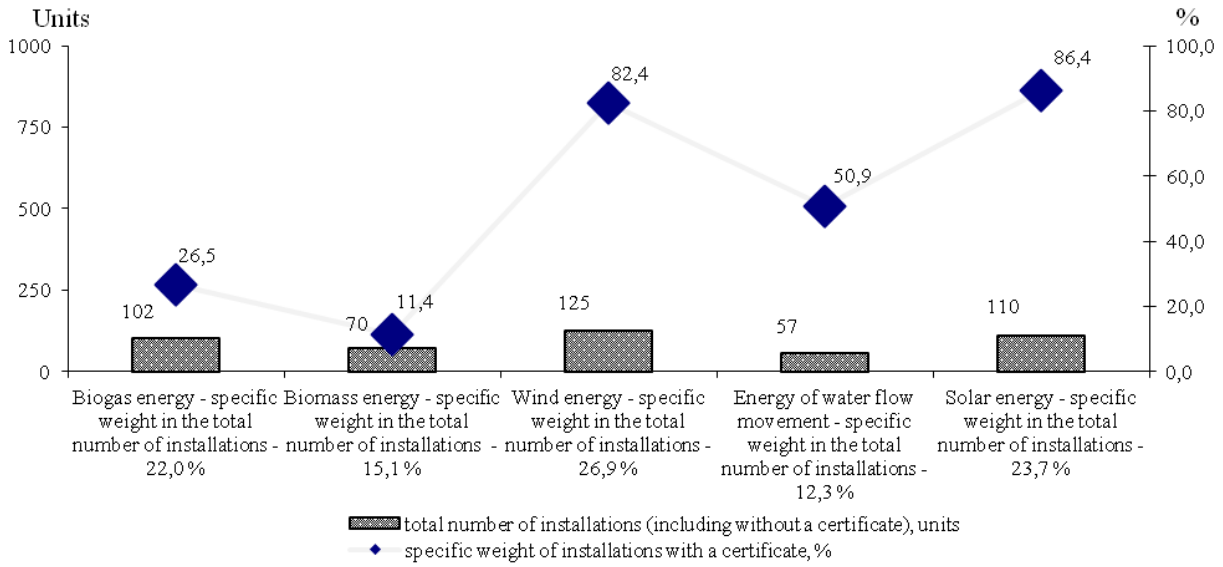
In the Republic of Belarus, there are 464 installations of alternative energy sources (including without obtaining a certificate for generated energy), 125 installations of those are wind energy sources, 110 – solar. The highest percentage of certified energy is recorded according to these installations (figure).

energy sources: Resolution of the Council of Ministers of the Republic of Belarus, August 6, 2015, no. 662 (as amended by Resolutions of the Council of Ministers dated 03.11.2021 no. 626) ; On foreign gratuitous aid: Decree of the President of the Republic of Belarus, May 5, 2020, no. 3 (as amended by Decree of the President of the Republic of Belarus dated 08.11.2021 no. 7) ; On approval of the concept of development of electric generating capacities and electric networks for the period up to 2030: Resolution of the Ministry of Energy of the Republic of Belarus, 25 February, 2020, no. 7 ; Tax Code of the Republic of Belarus (special part), dated 29.12.2009 no. 71-Z (as amended. Laws of the Republic of Belarus dated 29.12.2020 no. 72-Z). Articles 119 and 239.

[2] The analysis was carried out on the basis of data from consolidated annual reports of organizations of the Ministry of Agriculture and Food of the Republic of Belarus.

[3] When performing calculations in foreign currency in relation to a specific year, the actual US dollar exchange rate was taken based on data from the National Bank of the Republic of Belarus (2000 – 320 rubles for 1 USD, 2015 – 15905.05 rubles, 2020 – 2,439 rubles for 1 USD.

[4] The calculations are based on the data of consolidated annual reports of organizations of the Ministry of Agriculture and Food of the Republic of Belarus.



Number of alternative energy installations in the country and their specific weight, taking into account the certificate availability

N o t e. The drawing was compiled by the author according to the data of the Ministry of Nature and Environment of the Republic of Belarus.

At the end of 2018, installations operating using circulating energy sources, legal entities (not part of Belenergo) and sustainable entrepreneurs produced 435.8 million kWh of electricity. The largest operating installations for the use of solar energy: Solar power plant at the head facilities of RUE "Belorusneft", Rechitsa – 55.20 MW; Solar power plant near the flax mill in Smorgon – 18.63 MW; photoelectric power plant in the village of Soboli (Braginsky district) – 18.48 MW; Solar power plant near the settlement Vishenki – 14.25 MW. According to the research results, 22 districts were identified as the most promising for development of wind energy in the republic: Grodno region: Grodno, Oshmyany, Smorgon, Novogrudok, Korelichy districts; Brest region: Baranovichi district; Minsk region: Volozhin, Molodechno, Nesvizh, Slutsk, Lyuban districts; Vitebsk region: Verhnedvinsk, Gorodok, Tolochin, Orsha, Liozno districts; Mogilev region: Shklov, Mogilev, Goretsk, Dribinsk, Chaussy, Mstislavl districts. Biogas energy can be generated in the following areas: biogas plants of agricultural organizations, biogas plants at sewage treatment plants, biogas plants on municipal waste, biogas plants on food production waste[5].

At the state level, an active policy is being pursued to support the industrial development of energy from alternative sources, a feature of which is a list of tax benefits with the availability of quota levels, for the justification and distribution of which at this stage there are no comprehensive scientific and practical or scientific and methodological recommendations[6]. The majority of scientists-economists regarding the problem of using alternative (decentralized) energy sources in their research address the following problems [4, 6–9, 14, 16, 22, 25–29]: analysis of energy-saving technologies used; evaluation of the energy and economic efficiency of alternative energy sources application; development trends directions for use of alternative energy sources; control mechanisms for creation and use of alternative energy sources; the importance and influence of alternative energy sources in development of the national economy; governance alternative energy sources; increasing the economic efficiency of alternative and renewable energy sources. However, inherent in the studied works, the principles (targeting the creation of alternative energy sources; risks the creation of alternative energy sources; the conflicts over creation of alternative sources of energy; diversity; the need for synchronization with the electrical networks;

[5] Mihalevich R. V., Narkevich I. P., Kon'kova V. M., Gonchar K. V., Meleh D. V. National Report on the state of the environment in the Republic of Belarus. Minsk, Belarusian Research Center "Ecology" 2019. 191 p.

[6] On the establishment, distribution, release and withdrawal of quotas for the Creation of installations for the use of renewable energy sources: Resolution of the Council of Ministers of the Republic of Belarus, August 6, 2015, no. 662 (as amended by Resolutions of the Council of Ministers dated 03.11.2021 no. 626).

territorial selectivity, etc. At the same time, studies have been laid in the field of substantiating the work (targeting the creation of alternative energy sources; the riskiness of creating alternative energy sources; the conflict nature of creating alternative energy sources; identifying the danger of creating networks and thermal installations for general use; territorial selectivity, etc.), trends in the energy sector (price volatility, variability of economic and organizational efficiency of energy use in different regions and industries; low human resource potential of energy production and use at the level of individual economic entities; ambiguous environmental efficiency; activation of the commercial component of energy production and sale; technical potential of energy production, etc.), management functions (planning, organization, coordination, control, etc.) [1, 3, 7, 25–27], scientific and theoretical foundations of research have been taken into account and laid down.

In this context, it is necessary to develop common approaches to assessing the significance of the use of alternative energy sources by specific sectors of the national economy (which is associated with different levels of comparative utility in the production and further use of products obtained from alternative sources; the impact of energy on the environment; infrastructure maintenance costs, etc.), energy consumers, paying special attention to the agri-food sector as a producer of energy from alternative sources (for example, the use of biogas plants), and the consumer. In this regard, it is required to effectively manage the energy of alternative sources through quotas, taking into account the characteristics of individual regions. The solution of this problem was laid in the basis of the proposed scientific and methodological provisions for the choice of the consumer of energy produced on the basis of alternative sources, which is connected with the differentiation of prices within and outside the allocated quotas, as well as the terms of operation of installations for the use of renewable energy sources[7]. The development includes the following elements [13]:

1) end-to-end system of indicators (coefficients, indicators) of the efficiency of using alternative energy sources:

– *for the state:* metal goods; tax burden; the level of subsidies to the industry because of the disparity of prices for resources and products of certain industries; sustainable level of ensuring energy and food security; individual coefficients for the balanced development of rural areas and businesses in the village; the performance indicators of agricultural producers; development indicators of green economy; the cost of developing energy infrastructure to expand the area of its consumption; the volume of emissions into the atmosphere and discharges into the water of pollutants; the source of energy generation and the cost of utilization of certain types of resources that are strategic for the production of this energy;

– *for the energy supplier:* a) in case of priority use of energy for their own purposes: the size of the profit from sales generated by own resources, energy intensity of production in value and volume terms, the size of the profit from sales of conventional units of energy resource; b) in case of priority of a commercial approach to energy production: the level of energy losses; timeliness of payment for the consumed energy; the coefficients of the stability of compliance with the hourly chart of energy consumption; the coefficients of coherence and adjustment of schedules and energy consumption rates; the possibility of cooperation and resource offsets (e.g., equivalent exchange chicken manure, animal waste and thermal energy); access to a common grid; source of energy production and cost of maintenance;

– *for product manufacturers* (population, farmers, agricultural producers, processors of agricultural raw materials, other areas of real interest): the proportion of the cost of energy resources in product costs; energy production; cost of depreciable assets; the structure of the attenuation, including energy facilities; possibility of using energy at any time of day and year; marketability of production;

– *for end-users of* products (manufacturing organizations, wholesale and retail trade, catering organizations, etc.): the final cost of products;

2) the algorithm for implementing the choice of the consumer of energy generated on the basis of alternative sources includes the following steps, implemented in digital format (table 1):

stage 1: justification of the volume of commercial energy and possibility of its implementation;

stage 2: generating applications through the assessment of real energy demand;

[7] On tariffs for electricity produced from renewable energy sources: Decree of the Ministry of Antimonopoly Regulation and Trade of the Republic of Belarus, September 3, 2018, no. 73 (as amended by Resolutions MART dated 10.06.2021 no. 45).

stage 3: identification of a potential energy consumer;

stage 4: approval of the unified energy balance schedule and its subsequent adjustment;

3) conditions for considering an agricultural producer as a consumer of alternative energy sources:

well-established production of agricultural products with not always sustainable effectiveness;

productivity indicators reach average levels;

a relatively high level of material consumption, energy consumption of products (high levels of these indicators require a complete modernization of the technical and technological process);

availability of a set of measures, resource and energy saving programs;

technical and technological possibility of using alternative energy sources in implementation of certain types of agricultural products;

low level of natural losses of products during storage and sale;

high marketability of manufactured products;

T a b l e 1. **Algorithm of actions for determining the potential consumer of alternative energy sources**

Subjects and list of actions	Implementation features of the stage
Stage 1	
The energy producer: 1.1. Submits a list of indicators that characterize the production and use of energy in the form of reports to the district executive committee (in the context of two options: on average for the last three years and for the last year)	According to the list of actions, the presentation of indicators by blocks: **energy indicators:** *natural energy indicators that characterize the production unit:* the amount of energy produced, including taking into account its certification; the amount of energy spent for your own needs; watch the corridors of the generation and use of energy; the power of the generated energy and its type; potential energy level for commentary purposes; potential risks of power generation failure; variable energy production costs in physical terms **energy and product indicators:** *cost energy and product indicators that characterize the production and sales unit:* variable costs of energy production in terms of value; revenue from the sale of products (services) produced using alternative energy sources; profit from the sale of products (services) produced using alternative energy sources *specific energy and product indicators that characterize the production and sales unit:* energy intensity of products (services) produced with the use of alternative energy sources (in physical and cost terms); the specific weight of energy costs in the cost of production; revenue from the sale of products (services) per conventional unit of energy consumed; profit from the sale of products (services) per conventional unit of energy consumed
Representatives of the district executive Committee: 1.2. Formation of a unified database of indicators that characterize the production and use of energy, and determination of the index of attractiveness of the supplier of energy resources	The attractiveness index is determined in two directions: first, from the point of view of the efficiency of using the opportunity for energy production, which is estimated through an integration coefficient calculated on the basis of indicators that characterize the production and use of energy. In the future, this will allow to: 1) evaluate the rationality of further granting this subject a quota for energy production; 2) assign this subject to the target energy category: producer-consumer; producer-supplier; producer-active supplier; secondly, from the perspective of whether the list of strategic sellers of energy resources, which is determined through the performance of natural energy indicators of the production unit (the amount of energy produced, including with regard to its certification; the amount of energy expended for its own needs; guards the corridors of the generation and use of energy; power, energy and species; potential energy levels of commercial purposes; potential risks of complete lack of energy production; variable costs for energy production in physical terms)
Stage 2	
Representatives of the district executive Committee: 2.1. Formation of an impersonal schedule of energy supply, taking into account its type and quantity	Development of a unified chart of the flow of energy in the quantitative composition with regard to the diurnal period and the risk of shortfall in the energy representation coefficients reduce energy tariffs, including taking into account the specified risks
2.2. Accepting applications for the required energy level	Formation of the application form for receiving energy generated by alternative sources

End of table 1

Subjects and list of actions	Implementation features of the stage
Product Manufacturers 2.3. Submission of an application for the need to use alternative energy source	Basic production and economic indicators: the required amount of energy and the possible time period of its receipt; type of economic activity; a list of products for the production of which energy will be spent; actual energy consumption of the product; cost of production; the share of fuel and energy resources in the cost structure; profitability of sales of products; profit per standard energy unit
Stage 3	
Representatives of the district Executive Committee: 3.1. Detailed analysis of information and assessment of the significance of each indicator for the national economy through a list of coefficient	Formation of a regional system of indicators on the level of significance and their impact on regional security, including economic, food, energy and social security at the level of the administrative region: economic security: all cost indicators should be a priority; food security: food and production indicators should be given priority, including their cost characteristics; energy security: energy indicators; social security: the cost of products and ensuring the possibility of implementing activities, including small businesses – integrated economic, energy and food security: individual indicators that characterize regional security (for example, the energy intensity of the region, the energy intensity of agricultural products, the list of energy-intensive types of agricultural products; profitability of sales)
3.2. Definition of corridors of indicators that characterize the efficiency of the use of alternative energy source	Justification of the appropriate upper and lower limits of indicators that allow organizations to qualify for the use of alternative energy sources
3.3. Identification of a potential energy consumer	Calculation of the significance ranks of potential consumers, taking into account regional security and corridors of indicators that characterize the efficiency of using alternative energy sources
Stage 4	
Representatives of the district executive Committee, energy producer, product manufacturers: 4.1. Approval of consumers of alternative energy sources and approval of unified energy supply schedule	Signing of a package of documents and approval of annual programs taking into account the use of alternative energy sources

N o t e. The table is compiled by the author on the basis of his own research.

4) evaluation corridors of indicators of the use of fuel and energy resources in agriculture (emphasis was placed on strengthening the food security of the region in relation to strengthening energy security) (table 2).

The practical application of this algorithm is advisable only at the level of districts that have a high-energy potential for using alternative energy sources, taking into account the possibility of increasing gross output in all sectors of the economy;

5) methodological approaches to the justification of energy-intensive regions, based on which we propose a six-stage algorithm of actions (table 3), a peculiar application of which is the need to adjust the boundary values of indicators that dominate at a certain stage. In this regard, we have identified the following conditions for recalculating indicators: technical and technological modernization in agriculture, changing the structure of sown areas, commissioning installations of alternative energy sources, etc.

Probation of the proposed algorithm of actions to identify energy intensive regions of the country with the expansion of the use of alternative sources of energy in agriculture on the example of the Brest region has allowed four of the districts, particularly requiring the use of alternative energy sources in the production of agricultural products, Baranovichi (integrated energy factor activity is 6.07), Bereza (integrated energy factor activity – 6.00), Brest (integrated energy factor activity – 4.80) and Kamenets (integrated coefficient of energy activity – 4.67) districts. Peculiarity of this development is the priority of the role of the state in the choice of the consumer, which is justified by the need [13]. Firstly, orientation to the equivalent earnings in the industries of national economy. Secondly, the high recycling cost of

certain types of resources, including the cost of their transportation. Thirdly, the creation of jobs in rural areas and small towns. Fourthly, the provision of energy infrastructure remote from the power sources of the country. Fifthly, the lack of a fair system of allocation of quotas for the use of energy from alternative sources, taking into account the low levels of its production and efficiency for the national economy of the country, and in particular rural areas. Thus, at the regional level, the size of quotas for the production of alternative energy sources should be considered and expanded.

T a b l e 2. **Regional framework levels of indicators**

Indicators	Agriculture		Industries			
			Crop production		Animal husbandry	
	from	to	from	to	from	to
Cost						
Material consumption, USD per USD 1000 of production	650	750	500	600	700	800
Energy intensity, USD per USD 1000 of output	70	120	90	150	40	80
Efficiency of funds per USD invested in material resources, USD	0,20	0,40	0,35	0,50	0,15	0,35
Efficiency of funds per USD 1 invested in energy resources, USD	0,06	0,17	0,12	0,25	0,05	0,10
Cost-natural						
Profit per 1 ton of fuel equivalent, USD	139	393	277	578	116	231
Natural-cost						
Energy consumption, kg of fuel per USD 1000 of manufactured products	210	276	310	450	140	175
Structural energy intensity for electricity and heat	35	45	30	38	40	49
Natural						
Energy consumption per 1 ha of agricultural land, kg of standard fuel	200	216	–	–	80	86
Energy consumption per 1 ha of arable land, kg of conventional fuel	–	–	190	240	–	–

N o t e. The table is calculated and compiled by the author based on the results of research. Calculations were made on the basis of actual data of production and economic activity of the best agricultural organizations in the context of districts according to 2017–2020; when performing calculations, the actual US dollar exchange rate was taken based on data from the National Bank of the Republic of Belarus (2017 – 1.9324 rubles, 2018 – 2.0377 rubles, 2019 – 2.0914 rubles, 2020 – 2.439 rubles for 1 USD.

T a b l e 3. **Algorithm of actions to identify energy-intensive regions of the country, taking into account the expansion of the possibility of using alternative energy sources in agriculture based on the principles of a system-situational approach**

Action stage	The indicator that dominates at a certain stage and features of the calculation	Levels	Limit values of the indicator	The corresponding value of the energy activity coefficient
1. Determination of the district level by the amount of fuel and energy resources used in agriculture	The amount of fuel and energy resources used, expressed in tons of conventional fuel	Low consumption level	Up to 15000	1.0
		Relatively low level of consumption	15 000–20 000	2.0
		Average consumption level	20 000–25 000	3.0
		High level of consumption	25 000–30 000	4.0
		Ultra-high level of consumption	Over 30 000	5.0
2. Determining the level of the district by the amount of electricity and heat used in agriculture	The amount of electricity and heat used, expressed in tons of conventional fuel	Low consumption level	Up to 2000	1.0
		Relatively low level of consumption	2000–5000	2,0
		Average consumption level	5000–8000	3.0
		High level of consumption	8000–11 000	4.0
		Ultra-high level of consumption	Over 11 000	5.0
3. Determination of the energy intensity of agricultural products	Energy intensity of agricultural products, kg of fuel per US $	Low consumption level	Up to 100	1.0
		Relatively low level of consumption	100–120	2.0
		Average consumption level	120–140	3.0
		High level of consumption	140–160	4.0
		Ultra-high level of consumption	Over 160	5.0

End of table 3

Action stage	The indicator that dominates at a certain stage and features of the calculation	Levels	Limit values of the indicator	The corresponding value of the energy activity coefficient
4. Determination of the average coefficient of energy activity of the region by three indicators	The average coefficient of energy activity for three indicators (as the arithmetic mean of the coefficients that characterize the indicators: the amount of fuel and energy resources used; the amount of electricity and heat used; energy intensity of agricultural products	Low consumption level	Up to 2	1.0
		Relatively low level of consumption	2–3	2.0
		Average consumption level	3–4	3.0
		High level of consumption	4–5	4.0
		Ultra-high level of consumption	Over 5	5.0
5. Determination of the district level by alternative energy sources	The amount of fuel and energy resources of alternative energy sources used, expressed in tons of conventional fuel	There are no alternative energy sources	–	1.0
		Low output level	Less than 1000	1.1
		Relatively low output level	1000–3000	1.2
		Average output level	3000–5000	1.3
		High output level	5000–10 000	1.4
		Ultra-high output level	Over 10 000	1.5
6. Determination of the integrated coefficient of energy activity of the region	The average coefficient of energy activity is multiplied by the coefficient that characterizes the amount of fuel and energy resources used by alternative energy sources	Neutral level: does not require the search for alternative sources of energy production	Up to 3.5	White color
		Standard level: requires increased search for alternative sources of energy generation	3.5–4.5	Light blue color
		Dangerous level: particularly requiring the use of alternative energy sources in the production of agricultural products	Over 4.5	Blue color

N o t e. The table was compiled by the author based on the results of his own research based on an analysis of the actual data on the production and economic activities of the best agricultural organizations in the context of districts according to the data of 2017–2020.

Conclusion

Research on the development of organizational and economic solutions for the effective management of alternative energy sources in the context of strengthening food security in Belarus includes the following results:

1. The analysis shows that the quantitative consumption of fuel and energy resources in the country's agriculture over the period 2000–2020 tended to decrease: diesel fuel – 1.3 times, gasoline – 4.7 times, electricity – 1.8 times; cost of fuel and energy resources per hectare is reduced (for example, when cultivating grain from 60 to 54 USD/ha) and the energy intensity of individual crops decreases (for example, when cultivating grain from 31.5 to 16.3 USD/ton).

2. It has been established that the Republic of Belarus actively supports the development of alternative energy sources; conditions have been created in the country for the practical application of installations for generation of alternative energy sources (464 installations of alternative energy sources are in operation), issues of selling surplus electricity to consumers in any region of the country are being worked out, however, quota mechanisms for distributing energy between economic entities and regions of the country are a significant limitation.

3. Methodological bases for substantiation of the effective consumer of energy generated on the basis of alternative sources installations are proposed, including a through system of indicators of the efficiency of the use of alternative energy sources in the context of business entities; a multi-stage algorithm for implementing the choice of a consumer of energy generated on the basis of alternative sources (taking into account the allocation of individual subjects for the implementation of each stage, their distinctive characteristics, a list of actions, etc.); conditions for considering an agricultural producer as an effective consumer of alternative

energy sources; corridors of indicators of the use of fuel and energy resources in agriculture, taking into account the specifics of the development of individual regions of the country; methodological approaches to substantiation of energy-intensive regions. The scientific idea of the development is that for the first time, scientifically based approaches to the choice of consumers of alternative energy sources within quotas are proposed, taking into account the importance of their products, with a focus on strengthening food security in conjunction with strengthening the energy security of the regions.

The results of the research are intended for: management bodies of the regional economy and the agro-industrial complex in the formation of agreed decisions to justify the strategic directions for the development of the regions, including increasing the efficiency of using alternative energy sources; educational institutions of an economic profile in the development of curricula and lecture courses in the field of "Regional planning and management of energy supply and consumption processes: agro-industrial complex"; research institutions in implementation of scientific projects in terms of regional aspect of methodology and mechanisms for managing the long-term sustainability of the national agro-food system of the Republic of Belarus through energy supply and energy consumption.

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References

1. Daineko A.E., Padalko L.P., Tsilibina V.M. *Energy efficiency of the Belarusian economy*. Minsk, Belaruskaya navuka Publ., 2016. 363 p. (in Russian).

2. Zorina T.G. *Formation of the strategy of sustainable energy development*. Minsk, Misanta Publ., 2016. 332 p. (in Russian).

3. Gerasimovich L.S., Sapun O.L., Sinenkiy A.V. Method for scientific substantiation of agrarian complex energy system using local resources. *Vestsi Natsyyanal'nai akademii navuk Belarusi. Seryya agrarnykh navuk = Proceedings of the National Academy of Sciences of Belarus. Agrarian series*, 2019, vol. 57, no. 1, pp. 93-109 (in Russian). https://doi.org/10.29235/1817-7204-2019-57-1-93-109

4. Baitanaeva B.A., Shaikhutdinova A.K., Bisultanova N.S. Problems and perspectives of the use of renewable sources of energy: domestic and foreign experience. *Vestnik universiteta Turan = Bulletin of "Turan" University*, 2019, no. 3 (83), pp. 180-184 (in Russian).

5. Gusakov V.G., Rusan V.I., Prishchepov M.A., Zayats E.M., Kuzmich V.V., Dyachek P.I. (et al.). *Energy efficiency of agricultural production*. Minsk, Belaruskaya navuka Publ., 2011. 775 p. (in Russian).

6. Ayrapetova A.G., Lastovka I.V. Renewable energy sources as a new trend of the world energy market development. *Izvestiya Sankt-Peterburgskogo gosudarstvennogo ekonomicheskogo universiteta* [News of the Saint Petersburg State University of Economics], 2019, no. 5 (119), pt. 1, pp. 70-74 (in Russian).

7. Burenina I.V., Prokofieva P.E., Yakupova K.V. Theoretical approaches to estimation of economic efficiency of using alternative sources of energy. *Vestnik ekonomiki i menedzhmen*ta = *Vestnik of Economics and Management*, 2018, no. 2, pp. 12-17 (in Russian).

8. Korsak E.P., Mantserova T.F. Prospects for nuclear power development: a global and national perspective. *Mirovaya ekonomika i biznes-administrirovanie malykh i srednikh predpriyatii: materialy 15-go Mezhdunarodnogo nauchnogo seminara, provodimogo v ramkakh 17-i mezhdunarodnoi nauchno-tekhnicheskoi konferentsii "Nauka – obrazovaniyu, proizvodstvu, ekonomike", 24–25 yanvarya 2019 g., g. Minsk, Respublika Belarus'* [World economy and business administration of small and medium-sized enterprises: proceedings of the 15th international scientific seminar held within the framework of the 17th international scientific and technical conference "Science for Education, Production, Economics", January 24-25, 2019, Minsk, Belarus]. Minsk, 2019, pp. 79-80 (in Russian).

9. Mudretsov A.F., Tulupov A.S. Improving the economic effectiveness of non-traditional and renewable sources of energy. *Regional'nye problemy preobrazovaniya ekonomiki = Regional Problems of Transforming the Economy*, 2017, no. 5 (79), pp. 12-19 (in Russian).

10. Pavlenkov I.O. Economic problems of development of production and consumption of alternative sources of energy. *Neftegazovyi kompleks: ekonomika, politika, ekologiya: sbornik statei pobeditelei II konkursa, 21 aprelya 2016 g.* [Oil and gas complex: economics, politics, ecology: collection of articles of the winners of the 2nd competition, April 21, 2016]. St. Petersburg, 2016, pp. 219-227 (in Russian).

11. Titova E.S., Bondarchuk N.V. Theoretical improvement bases of key parameters management in creation and using alternative energy sources innovative processes. *Ekonomika i predprinimatel'stvo = Journal of Economy and Entrepreneurship*, 2016, no. 10, pt. 1, pp. 447-452 (in Russian).

12. Makrak S. Studying technique of fuel and energy expense resources and their detailed carrying out of analysis by agricultural production. *Agrarnaya ekonomika = Agrarian Economics*, 2019, no. 1, pp. 23-38 (in Russian).

13. Makrak S.V. Fuel and energy resources in agriculture of the Republic of Belarus: features of management and promising areas for improving efficiency. *Dolgosrochnye tendentsii razvitiya agroprodovol'stvennogo kompleksa Rossii v usloviyakh novykh global'nykh vyzovov: sbornik materialov Vserossiiskoi nauchnoi konferentsii "Ostrovskie chteniya"* [Long-term trends in the development of the agro-food sector in the context of new global challenges: proceedings of the All-Russian scientific conference "Ostrovsky Readings"]. Saratov, 2020, pp. 104-109 (in Russian).

14. Rudchenko G.A. *Improving the energy-saving system of agribusiness enterprises based on the use of economic tools*. Minsk, Institute of System Researches in Agroindustrial Complex of NAS of Belarus, 2020. 134 p. (in Russian).

15. Mandal B. Alternate energy sources for sustainable organic synthesis. *Chemistry Select*, 2019, vol. 4, no. 28, pp. 8301-8310. https://doi.org/10.1002/slct.201901653

16. Zocca R., Gaspar P.D., Silva P.D., Santos F.C., Andrade L.P., Nunes J. Decision-making computationally aided in the management of energy sources used in agrifood industries. *Energy Procedia,* 2019, vol. 161, pp. 100-107. https://doi.org/10.1016/j.egypro.2019.02.063

17. Bolyssov T., Yessengeldin B., Akybayeva G., Zhanseitov A., Sultanova Z. Features of the use of renewable energy sources in agriculture. *International Journal of Energy Economics and Policy*, 2019, vol. 9, no. 4, pp. 363-368. https://doi.org/10.32479/ijeep.7443

18. Uzair M., Sohail S.S., Shaikh N.U., Shan A. Agricultural residue as an alternate energy source: a case study of Punjab province, Pakistan. *Renewable Energy,* 2020, vol. 162, pp. 2066-2074. https://doi.org/10.1016/j.renene.2020.10.041

19. Novoselov A., Novoselova I., Potravnii I., Gassiy V. Conflicts management in natural resources use and environment protection on the regional level. *Journal of Environmental Management and Tourism*, 2016, vol. 7, no. 3, 407-415. https://doi.org/10.14505/jemt.v7.3(15).06

20. Novoselova I.Y., Novoselov A.L. Estimation of accumulated environmental damage: methods and experience. *Journal of Environmental Management and Tourism*, 2016, vol. 7, no. 4, pp. 619-624. https://doi.org/10.14505/jemt.v7.4(16).08

21. Berthouex P.M., Linfield C.B. *Energy management for pollution control*, 2018.

22. Rodriguez Borda C., Echeverri Martínez L.M. Renewable energies: the role of regulatory institutions to promote the use of alternative sources. *Revista Internacional de Cooperación y Desarrollo*, 2019, vol. 6, no. 1, pp. 47-62. https://doi.org/10.21500/23825014.3937

23. Skufina T.P., Samarina V.P., Krachunov H., Savon D.Y. Problems of Russia's arctic development in the context of optimization of the mineral raw materials complex use. *Eurasian Mining*, 2015, no. 2, pp. 18-21. https://doi.org/10.17580/em.2015.02.05

24. Zhaglovskaya A.V., Savon D.Yu., Safronov A.E., Sidorova E.Yu. Production activity analysis Methodology for open pit coal mines (in terms of shestaki open pit mine). *Eurasian Mining*, 2017, no. 1, pp. 14-16. https://doi.org/10.17580/em.2017.01.04

25. Gerasimovich L.S., Sapun O.L. Modern innovative approaches to the development of renewable energy in the Republic of Belarus. *Innovatsionnoe razvitie agropromyshlennogo kompleksa kak faktor konkurentosposobnosti: problemy, tendentsii, perspektivy* [Innovative development of the agroindustrial complex as a factor of competitiveness: problems, trends, prospects]. Kirov, 2020, pt. 2, pp. 275-283 (in Russian).

26. Gitelman L.D., Dobrodey V.V., Kozhevnikov M.V. Tools for sustainable development of regional energy systems. *Ekonomika regiona = Economy of Region*, 2020, vol. 16, no. 4, pp. 1208-1223 (in Russian). https://doi.org/10.17059/ekon.reg.2020-4-14

27. Rudchenko H., Zapolski M. Regional structural and functional model of energy saving in agroindustrial complex organizations based on the use of decentralized energy sources. *Agrarnaya ekonomika = Agrarian Economics,* 2019, no. 4, pp. 53-59 (in Russian).

28. Mantserova T.F., Lapchenko D.A. The main approaches to economic diagnostics of the power engineering enterprises. *Energetika. Izvestiya vysshikh uchebnykh zavedenii i energeticheskikh ob"edinenii SNG = Energetika. Proceedings of CIS higher education institutions and power engineering associations,* 2019, vol. 62, no. 4, pp. 362-376 (in Russian). https://doi.org/10.21122/1029-7448-2019-62-4-362-376

29. Tsiatsiorkina A., Lychahina K. Tendencies, prospects and economic incentives for renewable energy development. *Nauka i innovatsii = Science & Innovations*, 2019, no. 12 (202), pp. 41-47 (in Russian).

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