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ORGANIZATIONAL AND ECONOMIC MECHANISM OF ENERGY SAVING IN AGRICULTURE

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Original Article

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ABSTRACT

Globally, energy needs are increasing and leading to increased energy use on agricultural land. In this regard, in the face of growing environmental problems, it is extremely important to apply farming methods that maximize energy efficiency and save resources. This is the reason for the choice of the topic of the scientific article. The purpose of this study is to analyze possible ways of agroecological transition and develop recommendations on the organizational and economic foundations of energy conservation in agriculture. The article uses the methods of economic research: monographic, abstract-logical, computational-constructive, correlation-regression analysis, deterministic factor analysis, economic and mathematical modeling, etc. Results: in the context of the energy transition, agriculture faces a dual task: to reduce dependence on fossil fuels and provide society, in addition to food, with bioenergy to replace fossil fuels. The reality of this task depends on the ability of agriculture to achieve energy neutrality, that is, to balance external energy consumption with energy recovery from internal sources. This, in turn, depends on the political will of the states and the support of society. Conclusions: the most important principle of agricultural policy should be the search for harmonization of state energy policy and its consequences for the agricultural world with the goals of food production, combating soil artificiality, carbon accumulation in the soil, maintaining biodiversity and public health well-being.

Key words: *energy saving mechanisms, agriculture, agroecology, energy generation and storage, decentralization of energy production*

1. INTRODUCTION

Agriculture was once the main source of energy for pre-industrial societies and practically the only source of mechanical energy before the Industrial Revolution. The task of energy transition requires a new recognition of agriculture as an energy source capable of providing society, in addition to food, with bioenergy to replace fossil fuels. However, current agriculture is heavily dependent on fossil fuels and, therefore, it is far from a renewable energy system.

From the late 1960s to the present day, the role of energy in agri-food systems and, in particular, dependence on fossil fuels have been studied and evaluated with increasing research interest. An analysis of the energy metabolism of agricultural systems can provide insight into the structural deficit or excess of energy, as well as the complex relationships between energy consumption and productivity (Hryhoriv, 2019).

Agricultural transitions lead to structural changes in the energy exchange and food capacity of agriculture and emphasize the importance of industrial ecology approaches in promising agricultural modeling. The use of external resources makes it possible to eliminate internal productivity constraints and, in the case of fossil fuels, ensure high agricultural productivity due to depleted resources that disrupt the carbon cycle.

In this regard, the task of agriculture is to neutralize energy dependence on external resources through energy recovery from internal sources, which is very little studied in the scientific literature.

Energy neutrality in agriculture means producing the same amount of energy from domestic sources as consumption from external sources to support food production. Energy neutrality is a guarantee of food security in the face of volatile fossil fuel prices and potential shortages in the future, as well as a prerequisite for agriculture to become a clean source of energy for society. Only by achieving energy neutrality can agriculture contribute to bioenergy in the energy transition (Michurina et al., 2024).

Based on this, the relevance of the chosen topic is due to the fact that no study has gone beyond assessing the potential energy self-sufficiency of isolated crops or livestock systems.

Thus, the purpose of this study is to analyze possible ways of agroecological transition and to develop recommendations on the organizational and economic foundations of energy conservation in agriculture on the way to the transition to an environmentally friendly energy transition.

2. METHODS

The general methodological basis of the study was the dialectical method of studying economic phenomena and processes, the most important attributes of which are a systematic approach and system analysis. Within the framework of the system analysis, various techniques, methods and methods of economic research were used: monographic, abstract-logical, computational-constructive, correlation-regression analysis, deterministic factor analysis, economic and mathematical modeling, etc.

3. RESULTS

The renewable energy sector is the subject of numerous studies and therefore represents technological innovations in most energy sectors of the agricultural sector.

However, the key issue in the energy-saving approach in agriculture is the problem of energy storage. Energy storage and, in particular, electricity should be developed taking into account the necessary growth of renewable energy sources, some of which suffer from a lack of intermittency (wind and solar energy). This issue goes beyond the agricultural world. A single "reasonable" energy management by combining variable sources of production, main sources (nuclear) and additional sources (hydraulic, thermal power plants) will not be enough in the case of high rates of introduction of renewable energy sources, although it is desirable (the idea of smart grids) (Melnyk et al., 2018). Similarly, the distribution, that is, the distribution of objects across the territory in different climatic zones, is desirable, but not enough. In any case, the development of these energy sources will require the adaptation of distribution networks.

Since electricity itself cannot be stored, it must be converted into chemical, electrochemical, or mechanical energy. According to Christophe Guth, president of the National Alliance for the Coordination of Energy Research (Ancre), "we will have to develop breakthrough innovations in the field of electricity storage in order to support the growth of renewable energy capacity."

There are various storage methods, including STEP, batteries, compressed air and hydrogen. "Power to Gas" technologies allow storing electricity in the form of gas: this involves obtaining water by electrolysis (a water molecule is destroyed by electrical energy using rare metals such as platinum), dihydrogen — or H2, the smallest existing molecule, more often called hydrogen, which can be stored (which can create safety problems), transported, and then used for various purposes: mobility, hydrogen or electricity generation using fuel cells (PAC).

Other energy storage technologies are still at the stage of simple ways: supercapacitors, turbomachines, solid oxide fuel cells ("Solid Oxide fuel cell"), which allows you to consume a wide variety of fuels containing a mixture of hydrogen and carbon (natural gas, coal gas, biogas, etc.), flowing batteries ("Redox Flow"), steam reforming (Grift et al., 2017).

Despite the fact that many projects on environmentally friendly energy-saving technologies exist and are developing, the industry faces a number of obstacles:

1. Adverse macroeconomic costs

Despite ambitious goals for the development of bioenergy, renewable energy production in the agricultural sector remains subject to a number of uncertainties, especially due to a lack of economic profitability. No sector of renewable energy of agricultural origin is currently economically viable without government support. Therefore, their future depends on improving their energy efficiency, raising prices for other types of energy (for example, by increasing the cost of carbon dioxide emissions) or maintaining sufficient incentive support policies. Moreover, if the fact of integrating their externalities, in particular their positive externalities, rather requires public support, their development always remains the subject of demonstrating their real environmental added value, which is still a matter of debate for some sectors, such as biofuels (Timofeev et al., 2017).

Similarly, their macroeconomic costs will be even more adverse if they lead to conflicts over land use and food production. That is why we must remain vigilant about their impact on future food security: the production of photovoltaic electricity on earth and, above all, biofuels, for example, largely consumes agricultural land.

2. Appalling microeconomic costs

At the microeconomic level, renewable energy sources often represent large investments for farmers with uneven and uncertain economic profitability, which is confirmed only after a few years. These microeconomic costs can paralyze and become a serious obstacle to the development of renewable energy sources in the agricultural sector.

The required investments depend on many parameters, but the amounts can be high, while banks are cautious and financial risks are real. The difficulty of accessing financing through bank loans for projects whose profitability is sometimes questionable is an obstacle to the development of renewable energy, and special financing programs implemented by banks could help eliminate this obstacle. Taxation, which is more focused on renewable energy sources, will be an important incentive signal to facilitate farmers' investments in their development.

Thus, direct energy production should indeed be profitable compared to delegating management to energy companies or buying energy on the market, but each project is specific and strongly depends on its context: the nature of the field and energy source, accessibility and proximity to it, the field, access to land, proximity to networks, the nature of the project leader (individual, collective, operator(s), community, agricultural cooperative, etc.), investment potential. As a result, farmers prefer to manage and develop their resources directly in a short-circuit logic, which also allows them to benefit from most of the value produced, not to mention that the longer the transportation of waste, the higher its cost to the farmer and its negative external consequences for society (Yasnolob et al., 2019).

If photovoltaic and wind energy have reached the level of industrial and commercial maturity, with energy companies playing a central role, which also make profits, farmers are often content to lease their land, and farm-scale methane still raises questions in the field of research and development.

3. The volatility of some renewable energy sources, such as wind energy and photovoltaic energy.

The use of renewable energy sources poses the problem of the volatility of some of them, such as wind and solar energy, especially photovoltaic energy. There is also often a time lag between the production of electricity (for example, solar panels operating only during the day) and its consumption to meet needs (for example, the use of electricity at night for lighting) (Maskell et al., 2013).

Synchronizing supply and demand is a technological challenge that takes the form of energy storage, especially electricity generated by wind and photovoltaic solar energy.

4. The technological problem of energy storage

As noted above, since the storage of electricity is impossible, it is necessary to convert it into the form of potential energy of a chemical or mechanical nature. Technological innovation will be necessary to support the growth of renewable energy sources in our energy mix. It should also be noted that energy storage solutions have costs (which can go up to double the cost of the technologies used, for example, in photovoltaic or wind energy).

5. Obstacles related to social acceptability

Public opinion should fully understand the problems of climate change and agro-energy transition, transparently using the most advanced scientific knowledge. The fact that social acceptability is uneven depending on the renewable energy sources under consideration requires the creation of a hierarchy of the most effective solutions that should be brought to the attention and explained to the general public.

6. Administrative complexity

For many renewable energy sources (e.g. methane, solar and photovoltaic), project development is limited by cumbersome administrative procedures. The administrative and legal complexity of creating and implementing projects is subject to significant regulatory constraints. In particular, the investigation procedures were considered excessively long: it takes several years to implement a methanizer project in France (there are cases that lasted more than 5 years!), whereas, for example, in Germany, several months would be enough (Timmons et al., 2014).

The administration should provide feedback on existing files and identify difficulties and difficult places in order to draw conclusions. Simplification of these procedures should continue in any case. An organization that would be an intermediary and universal center for assistance to farmers and procedures related to renewable energy sources could provide such simplification.

This is far from the main obstacle to the development of renewable energy, but reducing administrative and legal complexity would help to rationalize their implementation.

7. Lack of professional training

Training courses that, within the framework of secondary or higher education, consider agricultural operations from an energy point of view are rare. However, training is a major challenge in energy production in the agricultural sector to explore related issues, interactions, enhance and secure income and avoid usage conflicts. It is necessary to educate farmers on these issues as early as possible. Agriculture is being transformed to produce energy, and as Olivier Doher, president of France Gaz Renewables and director of FNSEA explained, "if there are changes in agriculture, there are 'changes in learning'. Francis Clodpierre believes that one of the reasons for the failure of methane projects in France is the lack of training, blaming the presence of only four agricultural universities that offer certification training (Renewables, 2018). Moreover, it should be not just about the training of farmers, but also about all related professions (repairmen, electromechanics, analytical laboratories, etc.). The connection of agricultural secondary schools and professional secondary schools in the field of energy would also be relevant.

Training of energy producing farmers and, in particular, methane farmers seems necessary, since they are most often themselves involved in energy production in this sector.

Other sectors, such as wind power or photovoltaic (PV) energy, seem to require less training for farmers, since the latter's actions are not directly involved in energy production. In this case, special attention could be paid to economic models and the place of renewable energy in the economic balance of the enterprise.

4. DISCUSSION

Although it follows from this study that different energy sources in the agricultural world show opposite results in terms of advantages and disadvantages, especially in terms of social acceptability, yield or, above all, environmental impact, it is important to develop an energy transition in light of the complementarity of energies. There will be no single solution, and several renewable energy sources will have to be mobilized at the same time, among the latter biogas is particularly in need of development.

Within the framework of this study, the authors of the work have made some recommendations on the draft law on agricultural lands, which could become a vector for the reform of the agricultural world in favor of agroecology.

1. This first sentence is general and highly political in nature. As the most important principle, he puts the search for harmonization of state energy policy and its consequences for the agricultural world with the goals of food production, combating soil artificiality, carbon accumulation in the soil, maintaining biodiversity and public health well-being. This reconciliation should make it possible to ensure the priority of food production over other activities in the agricultural world in order to prevent the risks of conflicts of use.

Integrating public health among these priorities aims to articulate the interdependent issues of health, environment, food, agriculture and energy in a transversal and systemic vision. Our largely globalized agriculture and food affect the environment – harm biodiversity, pollution, global warming, soil quality – and shape our gut microbiota and our entire planet's immune system – a factor of resistance or vulnerability to infectious diseases. While our health policy often intervenes at the end of the race, on the care aspect and very rarely on the prevention aspect, although these topics are interdependent. This observation requires thinking about the contribution of agriculture to energy supply in this broad and end-to-end framework in order to avoid the reverse effect 188 and identify possible synergies (Owusu & Asumadu-Sarkodie, 2016).

2. To clarify the national energy strategy in relation to the agricultural world and, more generally, to improve the internal coherence of the State's energy policy in terms of the development of renewable energy sources by strengthening the role of Parliament.

This concern for improving the internal coherence of state energy policy in terms of the development of renewable energy sources, thanks to strategic interministerial management in the logic of the project, is relevant for the agricultural sector, but the authors noted the opportunity for other work, its relevance for carbon storage, disaster management, air pollution, the use of glyphosate or even the regulation of phytosanitary products (IRENA, 2018).

In addition, Parliament's role in defining and monitoring the national energy strategy should be strengthened. Such a provision is going in the right direction, but it will need to ensure that it does not limit Parliament's role to that of a legislator setting broad common goals: Parliament should be able to define renewable energy development goals for each sector, not just by type of energy, namely electricity, heat, fuel and gas. The responsibility for personal protective equipment should lie with Parliament, and the regulatory approach should only be used to establish a fine level of detail, and in no case to establish general guidelines by sector.

3. Support research on energy production in the agricultural sector and encourage the financing of innovative approaches, in particular the addition of an agricultural component to the energy research strategy

True to their role as a bridge between the political world and the world of research, the authors call for this third proposal to support research on energy production in the agricultural sector and encourage the financing of innovative approaches.

Such support requires the mobilization of existing systems to enrich them with an agricultural component. Therefore, a renewable energy research strategy should include an agricultural component.

In addition, the innovative use of ICTs and their applications, especially with the use of artificial intelligence (AI), which allows the creation of intelligent energy networks (smart grids), should be as broad as possible. For this purpose, basic and applied research, as well as R&D, can be mobilized before their dissemination and commercialization (Kvon et al., 2018).

4. Ensure regular and rigorous monitoring of energy production in the agricultural sector, integrating life cycle analysis approaches as much as possible.

Although energy production is not subject to regular monitoring by public authorities, it is proposed to ensure regular and strict monitoring, integrating approaches as much as possible from the point of view of life cycle analysis, which involves the creation of questionnaires on energy production in the agricultural sector (Korovin et al., 2018). This can be implemented in the form of a general agricultural census and annual agricultural statistics, but at the expense of expanding the scope of the study. Moreover, this data should be publicly available.

5. Promote energy production and consumption in the agricultural sector through incentives to stimulate the attractiveness of business models for farmers, by adapting regulated prices, holding tenders and open windows, using the lever of agricultural taxation and by removing certain regulatory obstacles to energy production and consumption in the agricultural sector. This proposal should be operational and will require the mobilization of the Government and Parliament to stimulate energy production and consumption in the agricultural sector.

First of all, we are talking about the continuation and purposeful expansion of the incentive system, which allows stimulating the attractiveness of business models for farmers by adapting regulated prices, holding tenders and open meetings. For example, certain thresholds for open meters need to be raised, especially with regard to methane and rooftop solar energy 194 in order to facilitate agricultural projects.

It would also be appropriate to consider using the lever of agricultural taxation by increasing the ability of farmers to link income from energy production to the agricultural profit regime.

Finally, certain regulatory barriers to energy production and consumption in the agricultural sector or in nearby areas need to be eliminated, for example, by simplifying administrative and permitting procedures for renewable energy projects in order to encourage the agricultural world to acquire its own energy sources, energy production facilities and facilitate its own consumption. Such development should take place without reducing the requirements related to safety and the environment.

Any government policy should encourage the appropriation of energy production infrastructure by farmers and their groups, not just by energy companies or third-party operators. The fact that the agricultural world is encouraged to purchase its own energy production plants is especially noticeable in the wind and photovoltaic sectors, in which farmers are often content with providing land resources. A similar principle would also make it possible to change the views on these sectors.

Similarly, the sale of energy produced by them is today the dominant economic model for farmers, but it is necessary to promote the development of their own consumption. They should be able to use the energy they produce on farms, for example by using more solar heat pumps and local biogas, and by allowing agricultural machinery to use alcohols and oils produced for the biofuel sector, the use of locally produced biomethane fuels should be allowed.

Living off food production is a source of pride for many farmers, and the same will happen with energy production. In this regard, small wind energy, small hydroelectric power and geothermal energy are suitable solutions for self-consumption on a farm scale.

Without being the subject of an incentive policy, own consumption on the farm remains very limited. Energy production in the agricultural sector can meet the needs of the farms themselves and/or local consumers in the logic of a territorial closed-loop economy. Therefore, it is necessary to promote local consumption at the farm level or in nearby areas, where possible, in “energy communities”. In many cases, especially in the case of methane, wind power or photovoltaic power, connection to gas and electric grids should remain the main goal, but the incentive for self-consumption and the development of technological solutions adapted to the size of farms will contribute to the production of energy by farmers. It would be possible to introduce a system to stimulate own consumption, even if public policy should continue to give priority to the introduction of biogas or electricity into the grid (Daioglou et al., 2016).

The growth of renewable energy sources, which are local sources of energy, will lead to a transition from a centralized energy system to a more distributed world. This is a transition period full of opportunities, but also risks, so it will need to be supported.

6. The deployment of territorial energy production projects in the agricultural sector within the framework of the territorial planning policy.

The authors recommend a territorial approach to energy production in the agricultural sector, integrated into the policy of regional planning. Therefore, the latter should be enriched by an energy policy of territorial agricultural origin, which does not take into account local peculiarities in territorial projects, and which can reach participation mechanisms, with or without "energy communities".

There is work to be done to rationalize and improve the most effective business models adapted to territories and various agricultural systems. The dissemination of these business models should be carried out through enhanced territorial coordination with the participation of local stakeholders, agricultural chambers and professional organizations representing the agricultural sector.

Partnerships can take many forms, here are some examples:

- a contract for the purchase and sale of thermal energy (hot air or hot water);
- a contract for the purchase and sale of biomass for a collective boiler house;
- a contract for the supply of animal husbandry waste for the mechanization installation and, conversely, waste disposal for the methanizer (in the case of sewage sludge);
- lease of land for wind or photovoltaic installations in exchange for agricultural land development;
- participation in a legal structure and/or a joint project;
- a contract for the sale of vegetable oils for municipal fleets, a contract for the sale of electricity or other network.

Several local players with funding or even common equipment (for example, a centralized boiler room) should participate in the deployment of certain solutions. These solutions increase the acceptability of renewable energy sources for society, especially when crowdfunding provides economic benefits for territories.

These territorial projects can also help to unite the rural and urban world in common views, the first of which is not very dense, but contains resources that allow energy production, including land, while the second is more often a consumer.

7. Adopt an approach to certification of ongoing projects, for example, in the form of labeling "Agroenergetics".

It would be advisable to initiate a certification process for ongoing energy production projects, for example, using labeling. They can exist at the industry level or be the subject of an integrated approach under one name. In this case, the authors propose the labeling "Agroenergy", which will meet the challenges and risks identified in this study. Labeling will be aimed at projects that prevent conflicts of use (agrivoltaism, sustainable methanization, etc. d.), respect the priority of food production, use life cycle analysis, or even be part of a territorial approach (Springmann et al., 2018).

8. Improve training in energy production in the agricultural sector at the level of initial training (secondary and higher), as well as continuing education, with certain training courses designed to acquire high-level skills, including those related to the installation and operation of power plants

Awareness-raising among farmers, as well as among agricultural technicians and consultants, about the problems of energy production in the agricultural sector should begin at the initial training stage, in secondary and higher education, and then continue in continuing education.

In addition to awareness and dedication, certain training courses should ensure the acquisition of high-level skills, including those related to the assembly and management of power plants. If wind energy and photovoltaic energy are known and widespread, this is often the result of a lack of knowledge about other technological solutions, such as methane, and the mobilization of participants outside the agricultural world (energy specialists and developers), which sometimes push for simple turnkey solutions, but not always beneficial in terms of profits for the agricultural world. Energy production takes a long time, but the workload of farmers varies depending on the sector, and this leaves more or less room for diversification of their activities.

It is likely that training on energy production in the agricultural sector will enable farmers to develop more independent and informed strategies.

9. To protect agricultural lands with the help of a new legislative framework

As we have already seen, agricultural land is not always available, and artificial cultivation of land every year leads to a further reduction in available land resources (Shadrina, 2020). This is one of the obstacles to the development of renewable energy sources, some of which, such as biofuels or terrestrial photovoltaic electricity, consume a lot of land and can cause conflicts of use that harm food crops (plants and animals).

First of all, it should be about bringing these reflections to a proposal for a new legislative framework aimed at better protection of agricultural land. This future bill may also become a vector for the reform of the agricultural world in the sense of a general orientation in favor of agroecology in a transversal and systemic vision of the interdependent issues of health, energy, environment and agriculture.

5. CONCLUSION

As for the key factors that make renewable energy sources a vector of rural development, the authors suggest:

- Integrate energy strategies into the strategy of local economic development so that they meet local potential and needs;
- Integrate renewable energy into broader rural economic supply chains such as agriculture, forestry, traditional industry and green tourism;
- Limit subsidies in both volume and duration and use them only to support renewable energy projects that become economically viable;
- Avoid imposing renewable energy sources on regions that are unlikely to be able to accept them;
- Focus on relatively mature technologies such as biomass heat generation, small hydropower and wind energy;

- Create a unified energy system based on small networks capable of supporting production activities;
- Recognize that renewable energy sources compete with other sectors for resources, especially land;
- Evaluate potential projects based on investment criteria, rather than based on short-term subsidy levels;
- At the local level, gain the support of the population by providing them with clear advantages and involving them in this process.

As for the obstacles, the authors point out that bioenergy is not synonymous with sustainable energy. The sustainability of bioenergy largely depends on how biomass is produced and used. Biomass production and use are not necessarily sustainable, for example, if they have a negative impact on people, the environment or natural resources and may jeopardize the ability of future generations to meet their needs.

Bioenergy is also associated with environmental and socio-economic risks for rural areas. For example, land-use change, intensification of forest management, or intensive cultivation of energy plants can lead to a reduction in biodiversity, soil degradation, water stress, or water pollution. Burning wood biomass can also lead to increased emissions of some harmful air pollutants, and discussions are ongoing about whether this type of biomass is truly carbon neutral.

Finally, the authors emphasize the problem of data scarcity: there is no comprehensive information on the number of projects, the amount of energy produced from renewable sources, or installed capacity. Therefore, it is impossible to quantify the contribution to the introduction of renewable energy sources in rural areas. In the absence of up-to-date and reliable information on renewable energy sources, it is impossible to assess the effectiveness of these measures.

Thus, sustainable agriculture occupies a primary place in the era of intelligent farming or smart farming. In the context of the energy transition, agriculture faces a dual task: to reduce dependence on fossil fuels and provide society, in addition to food, with bioenergy to replace fossil fuels. The reality of this task depends on the ability of agriculture to achieve energy neutrality, that is, to balance external energy consumption with energy recovery from internal sources.

REFERENCES

Daioglou, V., Stehfest, E., Wicke, B., Faaij, A., van Vuuren, D. (2016), Projections of the availability and cost of residues from agriculture and forestry. *GCB Bioenergy*, 8, 456-470.

Grift, D. R., Monkirif, J. F., & Exert, D. J. (2017). Specified Moments of Modern Understanding the Notion of No-Till Farming System in the USA. *Grain*, 10 (139), 106-110.

Hryhoriv, Ya. (2019). The Enchanted Spring. Movement to the Desert - Prospects in spring? *Grain*, 1(154), 71 -76.

IRENA. (2018) Renewable Energy and Jobs: Annual Review. http://www.irena.org/publications/2018/May/Renewable-Energy-and-Jobs-Annual-Review-2018

Korovin, I.O., Medvedev, A.V., Neupokoeva, T.V. (2018). Waste management in coal and oil industry in context of alternative sources of energy development. *International Journal of Energy Economics and Policy*, 8(6), 114-119

Kvon, G.M., Prokopyev, A.I., Shestak, V.A., Ivanova, S.A., Vodenko, K.V. (2018). Energy saving projects as energy security factors. *International Journal of Energy Economics and Policy*, 8(6), 155-160

Maskell, B., Baggaley, B. and Grasso, L. (2013). Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise, Second Edition. *Productivity Press*. New York. USA.

Melnyk, S. (2018). Climate Changes are already Affecting Agriculture. *Agrarian Policy*, 4, 8-11.

Michurina N., Amosova A., Kosnikov S., Vasilieva D.& Y. Kholopov Y. (2024). Adaptation of agricultural technologies to climate change: ways to reduce environmental impact. *E3S Web of Conferences,* 510 (03017), 50-62. https://doi.org/10.1051/e3sconf/202451003017

Owusu, P.A., Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, 3(1), 1-14.

Renewables. (2018). Global Status Report, No. REN21. http://www.ren21.net/wp-content/uploads/2018/06/17-8652GSR2018FullReportwebfinal.pdf

Shadrina, E. (2020). Non-Hydropower Renewable Energy Sources in Central Asia: Assessment of Deployment Statusand Analysis of Underlying Factors. *Energies*, 13(11), 2963. https://doi.org/10.3390/en13112963

Springmann M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L. et al. (2018). Options for keeping the food system within environmental limits. *Nature*, 562, 519-525. https://doi.org/10.1038/s41586-018-0594-0

Timmons, D., Harris, J.M., Roach, B. (2014). The economics of renewable energy. Global Development and Environment Institute. Medford, MA: Tufts University. 52.

Timofeev, M. M., Viniukov, O. O., & Bondareva, O. B. (2017). The Interaction of Biogenic and Technical-Technological Factors at Sustainable Agro-Biocenoses Formation. *Balanced Nature Management*, 1, 43-49.

Yasnolob, I.O., Chayka, T.O., Gorb, O.O., Galych, O.A., Kalashnyk, O.V., Konchakovskiy, Ye.O., Moroz, S.E., Shvedenko, P.Yu. (2019). Using resource and energy-saving technologies in agricultural production as a direction of raising energy efficiency of rural territories. *Ukrainian Journal of Ecology*, 9(1), 244-250.