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RESEARCH OF THE ACTIVITIES OF PEASANT FARMS IN KAZAKHSTAN IN THE CONTEXT OF EFFECTIVE ENERGY CONSUMPTION

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Abstract. Some of the concepts that can be identified with agriculture in Kazakhstan include farmers and livestock breeders. Nowadays, the concept of agriculture is inextricably linked with the concepts of efficient energy consumption and "green" farming, thus there is a need to improve the use of renewable energy sources. Ensuring the efficient use of energy has advantages in the form of lower production costs and social benefits in the form of reducing carbon dioxide emissions to a level that does not harm the environment, in support of sustainable development of agricultural regions.

The purpose of the article is to analyze the impact of the use of renewable energy sources on the development of peasant farms. It is planned to identify factors related to renewable energy sources in terms of agricultural development, profitability, and their impact on the environmental component. In this context, an analytical comparison of installed renewable energy capacities and indicators of reducing the cost of CO_2 emissions due to energy-efficient technologies of the new generation was carried out.

Keywords: renewable energy sources, farms, energy consumption, economic efficiency, reduction of CO_2 emissions, simple linear regression.

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ТИІМДІ ЭНЕРГИЯ ТҰТЫНУ КОНТЕКСІНДЕ ҚАЗАҚСТАНДАҒЫ ШАРУА ҚОЖАЛЫҚТАРЫНЫҢ ҚЫЗМЕТІН ЗЕРТТЕУ

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Аннотация. Қазақстандағы ауыл шаруашылығымен сәйкестендіруге болатын кейбір тұжырымдамаларға фермерлер мен малшылар жатады. Қазіргі уақытта ауыл шаруашылығы ұғымы тиімді энергия тұтыну және "Жасыл" экономика ұғымдарымен тығыз байланысты, сондықтан жаңартылатын энергия көздерін пайдалануды жақсарту қажет. Энергияны тиімді пайдалануды қамтамасыз ету ауылшаруашылық аймақтарының тұрақты дамуын қолдау үшін көмірқышқыл газының шығарындыларын қоршаған ортаға зиян келтірмейтін деңгейге дейін төмендету түріндегі өндіріс шығындарын төмендету әлеуметтік артықшылықтарға ие.

Мақаланың мақсаты жаңартылатын энергия көздерін пайдаланудың шаруа қожалықтарының дамуына әсерін талдау. Атап айтқанда, ауыл шаруашылығын дамыту, рентабельділік және олардың экологиялық құрамдас бөлікке әсері тұрғысынан жаңартылатын энергия көздеріне байланысты факторларды белгілеу жоспарлануда. Осы тұрғыда ЖЭК-тің белгіленген қуаттары мен жаңа буынның энергияны үнемдейтін технологиялары арқылы CO2 шығарындыларының төмендеу көрсеткіштері бойынша аналитикалық салыстыру жүргізілді.

Түйін сөздер: жаңартылатын энергия көздері, шаруа қожалықтары, энергия тұтыну, экономикалық тиімділік, CO_2 шығарындыларын азайту, қарапайым сызықтық регрессия.

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ИССЛЕДОВАНИЕ ДЕЯТЕЛЬНОСТИ КРЕСТЬЯНСКИХ ХОЗЯЙСТВ В КАЗАХСТАНЕ В КОНТЕКСТЕ ЭФФЕКТИВНОГО ЭНЕРГОПОТРЕБЛЕНИЯ

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Аннотация. Некоторые из концепций, которые можно отождествить с сельским хозяйством в Казахстане, включают фермеров и животноводов. В нынешнее время понятие сельского хозяйства неразрывно связано с концепциями эффективного энергопотребления и «зеленым» хозяйством, таким образом, существует необходимость в улучшении использования возобновляемых источников энергии. Обеспечение эффективного использования энергии имеет преимущества в виде снижения производственных затрат и социальную выгоду в виде снижения выбросов диоксида углерода до уровня, не наносящего ущерба окружающей среде, в поддержку устойчивого развития сельскохозяйственных регионов.

Целью статьи является анализ влияния использования возобновляемых исочников энергии на развитие крестьянских хозяйств. В частности, планируется установить факторы, связанные с возобновляемыми источниками энергии, с точки зрения развития сельского хозяйства, рентабельности и их влияния на экологическую составляющую. В этом контексте было проведено аналитическое сравнение установленных мощностей ВИЭ и показателей снижения затрат на выбросы CO_2 за счет энергоэффективных технологий нового поколения.

Ключевые слова: возобновляемые источники энергии, крестьянские хозяйства, энергопотребление, экономическая эффективность, снижение выбросов CO_2, простая линейная регрессия

***Статья выполнена в рамках финансируемого проекта**: ИРН AP23487689 «Разработка экономико-математической модели повышения эффективности использования природных ресурсов в сельском хозяйстве Туркестанской области, предупреждающей климатические изменения»*

Introduction

The rationale for selecting the research directions is based on the existing need to enhance the efficiency of energy use in Kazakhstan's peasant and farming households. Against the backdrop of global climate change and increasing demands on countries, including Kazakhstan, to meet environmental commitments, the use of renewable energy sources in the agricultural sector is becoming a priority. Agriculture is heavily reliant on traditional energy sources, particularly hydrocarbons, making it highly sensitive to fluctuations in energy prices and, moreover, to any energy crisis.

This is due to the fact that Kazakhstan's peasant households face high electricity costs, limited access to renewable energy sources (Smagulova, et al., 2022), and are vulnerable to new weather conditions. Consequently, renewable energy sources can be considered an effective solution to achieve energy security goals and reduce carbon dioxide emissions in agriculture, aligning with the global decarbonization process. However, Kazakhstan faces challenges such as the limited availability of renewable energy sources in rural areas (Kabdullov, 2024), insufficient awareness among farmers about these energy technologies, and restricted funding to implement energy-efficient measures.

The aim of this study is to discuss the potential prospects for the use of renewable energy sources and the improvement of energy consumption efficiency in Kazakhstan's peasant and farming households. The research will examine the relationship between the level of energy independence in farming households and the growing interest in renewable energy sources, assess the economic feasibility of employing energy-efficient technologies in the country's agricultural sector, and offer practical recommendations for their further development.

Materials and main methods

Literature review

The analysis of renewable energy utilization in agriculture is being actively implemented in several countries, yet this topic is most relevant for Kazakhstan, as the demand for energy is growing, and it is necessary to minimize the negative environmental impact. These methods should be considered from an international perspective, as the experience of other countries, when properly applied, can be utilized in Kazakhstan's agricultural sector.

In the study titled «Understanding Farmers' Intentions and Willingness to Adopt Renewable Energy Technologies» (Elahi, et al. 2022), the authors sought to determine how readily farmers in Pakistan utilize photovoltaic water pumps. The primary focus was on the social feasibility of the technology and the willingness of farmers to pay a premium for clean electricity. The results showed that younger farmers with higher levels of education and income were more likely to adopt renewable energy, while others refrained, mainly due to financial constraints and limited awareness of the benefits of renewable energy. Such conclusions may be significant for Kazakhstan, as it appears that farmers might similarly face challenges in financing and understanding the advantages of renewable energy. Government

intervention through support programs and awareness-raising initiatives is required to expand knowledge and encourage farmers to adopt small-scale renewable energy technologies.

In the work «The role of research and development in green economic growth through renewable energy development» (Fang, et al., 2022), the authors examined the impact of renewable energy research and development (R&D) on the economic growth of South Asian countries. The study found that industrial growth and technological advancement are key factors in reducing CO_2 emissions and fostering economic growth through the integration of renewable energy. However, research on renewable energy adoption conducted in European countries could also be applied to others; for instance, Kazakhstan could benefit from the predominant implementation of renewable energy on agricultural lands. This would not only help limit emissions but also contribute to the development of rural areas through a green economy.

According to a study titled «Assessment of environmental sustainability: identifying the relationship between co_2 emissions and agricultural and renewable energy consumption» (He, 2024), traditional farming practices increase emissions, while renewable energy, conversely, reduces emissions and ensures sustainable development. As a country facing similar challenges in agriculture and energy, Kazakhstan could benefit from South Korea's successful experience in implementing renewable energy in the agricultural sector to reduce emissions and improve environmental conditions.

In the article titled «Renewable energy sources and sustainable agriculture: a review of indicators» (Bathaei, et al, 2023), the authors devote significant attention to renewable energy-based agricultural production and its potential minimal negative environmental impact. They also emphasize the importance of using modern methods for assessing the efficiency of renewable energy in sustainable agriculture. It would be beneficial for farmers and various governmental bodies to have new and more precise sustainability indicators that reflect the impact of renewable energy sources on Kazakhstan's agricultural sector.

In their article «Rational use of Agricultural land in Kazakhstan» (Yelemessov, et al., 2022) analyze the institutional frameworks for the effective use of agricultural land in Kazakhstan's multicultural economy. According to the authors, there is a serious issue regarding the organization of sustainable and competitive land use when forming rational land management. In the context of a developing land market, ensuring a high level of commodity production and sufficient profitability becomes a key task. The article also notes that improving land use efficiency in farms with different forms of ownership depends on increasing labor productivity, optimizing economic regimes, and maximizing the use of internal reserves.

In the article «Sustainable Development Agriculture in the Republic of Kazakhstan» (Tokbergenova, 2018) an author analyzes issues related to the sustainable development of Kazakhstan's agricultural sector, with the authors focusing on problems associated with ensuring sustainability in agriculture. The diversity of natural and climatic conditions, as well as the availability of extensive

pasturelands in desert and semi-desert regions, has made traditional agriculture an indispensable means of ensuring the country's food security.

Finally, the study titled «Renewable energy sources and sustainable agriculture» (Aldhshan, et al. 2021), discusses the importance of renewable energy in ensuring sustainable agriculture globally. This article also describes various methods for assessing extraterrestrial solar radiation and determining optimal locations for photovoltaic farms. These methods can also be applied to identify potential areas for the development of solar power plants in Kazakhstan, particularly in the southern and western regions, which appear to have the highest potential for utilizing solar resources.

Analysis

The global economy is experiencing a substantial rise in demand for energy and associated services, driven by the necessity to support socio-economic development and improve the population's quality of life. Energy supply is a fundamental component for meeting citizens' basic needs, such as lighting, heating, cooking, and access to communication, as well as for enhancing production capacity (Kaygusuz, 2007).

However, the growing reliance on fossil energy sources like coal, oil, and gas is contributing to a rapid increase in greenhouse gas emissions, which negatively impacts the environment (Van Ruijven, et al, 2009). Economic structures and the selection of fuel and energy resources directly influence the volume of these emissions.

Kazakhstan, as one of the countries with high greenhouse gas emissions per unit of GDP, faces the necessity to transition to renewable energy sources (RES) for heat and electricity production, alongside improvements in energy efficiency. These measures are regarded as key tools to mitigate the adverse effects on the climate and the environment (Wang, et al, 2024).

Thus, data were collected to compare the levels of agricultural activity and energy consumption over the period from 2014 to 2022 (Kim, 2021) (Medieva, et al., 2024). Second-order polynomial interpolation sums were employed to estimate the coefficients. There is an abundance of additional data for 2014 and 2020, and the coefficients for these years were calculated based on the given data sets. This method proves effective for applied analysis, particularly when high data recovery speeds are required, as well as for coordinating and stabilizing growth, taking into account their nonlinear nature.

For example, cross-analysis and linear regression procedures were used to study the efficiency of renewable energy sources in meeting various household needs. An economic efficiency analysis was thus conducted, based on the cost savings from gas consumption and the reduction of CO_2 emissions, enabling a forecast for the coming years.

Interpolation of RES capacity:

$$P(x) = a \times x^2 + b \times x + c \quad (1)$$

Where:
P(x) – the desired capacity in year *x;*
a, b, c – coefficients calculated based on data from 2014 and 2021.
For further research, we will also require the functions of simple linear regression:

$$Y = \beta_0 + \beta_1 \times X + \varepsilon \quad (2)$$

Where:
Y – the dependent variable;
X – the independent variable;
β_0, β_1 – the parameters we seek;
ε – the error (noise) not explained by the model.
And correlation:

$$r = \frac{\sum(X_i - \bar{X}) \times (Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \times \sum(Y_i - \bar{Y})^2}} \quad (3)$$

Where:
X_i, Y_i – values of the variables;
X, Y – mean values of the variables;
r – correlation coefficient.

Thus, polynomial interpolation (1) allowed us to calculate data for each year between 2014 and 2021, as well as 2022. However, the growth in capacity and the reduction in emissions vary due to the nonlinear nature of the function (see Table 1).

Table 1. Results of polynomial interpolation for 2015-2022

Year	Installed Capacity (MW)	CO_2 Reduction (tons)	Cost Savings ($)	Regional Capacity (MW)	Technological Efficiency (MW)
2014	100,0	200,0	150,0	120,0	130,0
2015	126,7	254,3	196,4	162,9	164,3
2016	157,3	316,9	253,7	212,6	205,7
2017	192,0	387,7	312,9	268,0	206,8
2018	230,7	466,9	372,9	329,1	310,0
2019	273,3	401,3	433,7	396,0	372,9
2020	320,0	650,0	495,4	468,6	503,6
2021	500,0	850,0	700,0	400,0	520,0
2022	553,3	964,3	790,7	485,7	587,1

Now, based on the available data, we will utilize the method of simple linear regression (2) to identify the relationship between the variables (see Figure 1).

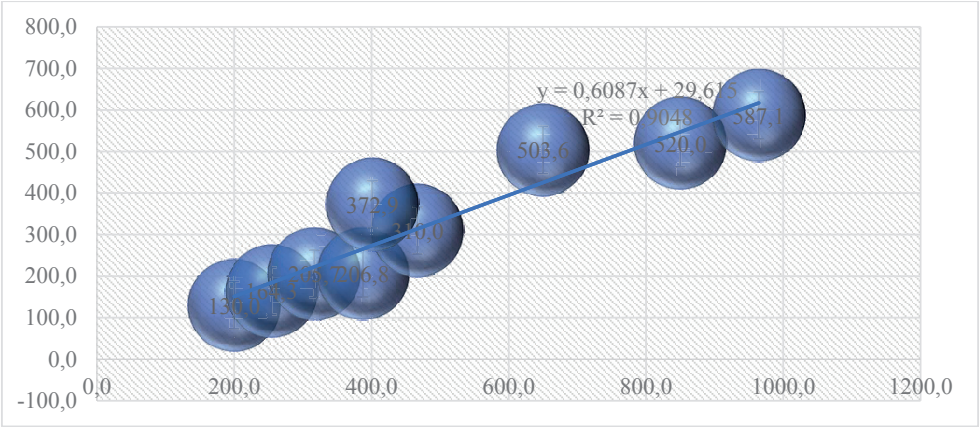

Figure 1. Simple Simple Linear Regression between CO_2 Reduction (tons) and Technological Efficiency (MW) based on the results of polynomial interpolation

Based on the regression, the linear regression function for our analysis is as follows:

$$Y = 0.6087x + 29.615 \quad (5)$$

Next, to verify the existing function, we should conduct a forecast function and the equation of the line (see Figure 2).

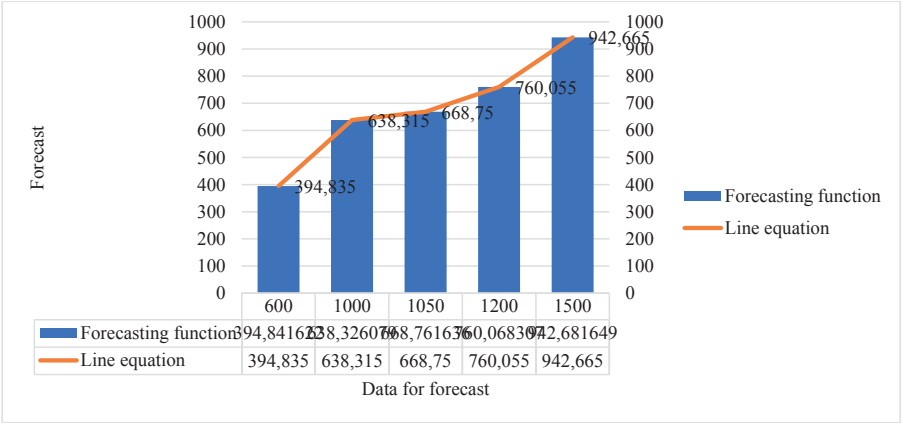

Figure 2. Forecast Function and Line Equation for CO^2 Reduction (tons) and Technological Efficiency (MW)

Now, we will identify the correlation using formula (3) for each parameter from Table 1 in relation to technological efficiency of RES (see Figure 3).

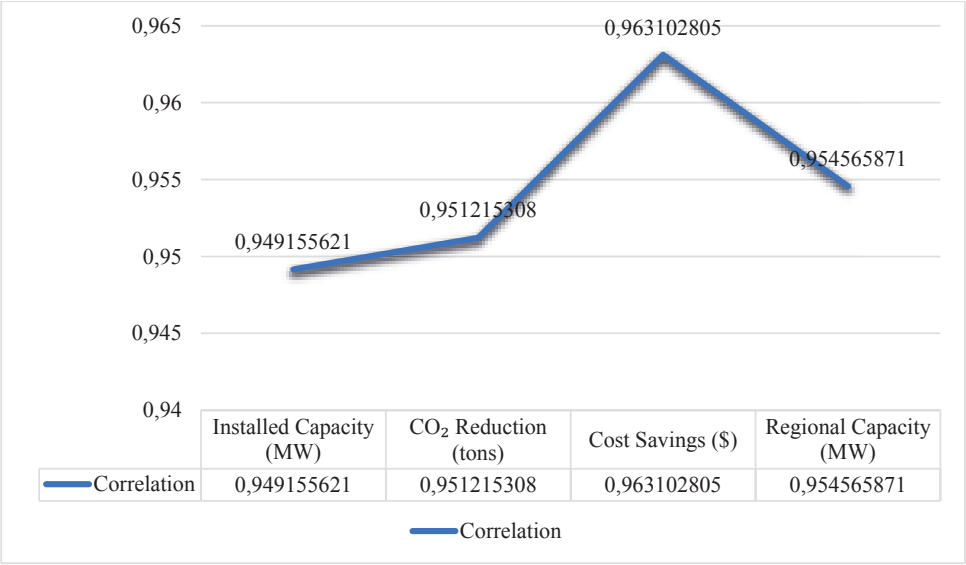

Figure 3. Correlation between Technological Efficiency (MW) and Installed Capacity (MW), CO_2 Reduction (tons), Cost Savings ($), Regional Capacity (MW)

The findings of the study revealed a high correlation (>0.94) between all the variables examined. Thus, it can be concluded that improvements in one indicator will inevitably lead to an increase in another. However, it is also important to note that even the presence of a positive relationship does not guarantee overall strong performance. For instance, the Republic of Kazakhstan is among the leading countries in terms of per capita carbon dioxide emissions, yet the proportion of the state budget allocated to financing environmentally significant technologies pales in comparison to the top 50 GDP-ranked countries. Based on this, we conclude that the country needs to focus on enhancing governmental support and fostering technological progress through funding the development and implementation of new efficient renewable energy sources.

The concepts of a "green economy," "green" growth, and sustainable development have brought together representatives of international organizations, government bodies, and civil society in response to recent global crises. "Green" growth aims to simultaneously achieve economic growth while addressing climate change, costly environmental degradation, and inefficient use of natural resources. In this regard, the development of the "green economy" agenda is seen as a comprehensive approach to overcoming the triple crisis: economic, energy, and environmental. Currently, the world is paying particular attention to issues of sustainable development and "green" growth. International organizations such as the United Nations, OECD, and the World Bank are actively working in this direction. The driving force of globalization is the modernization and transition of the global economy, particularly in industrially developed countries, to a new technological paradigm. This shift, alongside the

qualitative renewal of the technological base, increasing production efficiency, and enhancing the competitiveness of the economy, is aimed at improving the quality of life and living conditions. Globally, the economic policy of "green" growth was officially adopted by the Organization for Economic Cooperation and Development (OECD) in 2009 as a strategic direction for the long-term (up to 2030) and more distant (up to 2050) development of all its member states (Porfiryiev, 2013).

Despite the constraining effects of the crisis in the short- and medium-term outlook (until 2020), the importance of the "green" sector of the economy, particularly in the domain of clean energy, is expected to intensify. According to various forecasts, over the next 20–25 years, the vast majority of G20 nations are anticipated to witness rapid growth and a substantial increase in the share of the "green economy," with an emphasis on the development of environmentally sustainable energy sources (Chernomorova, 2016).

In Kazakhstan, the exploitation of renewable energy sources (RES) remains limited despite the considerable potential for their expansion. Nonetheless, the nation is making significant strides toward sustainable development, as evidenced by its ratification of the Paris Agreement in 2016 (The Law of the Republic of Kazakhstan dated November 4, 2016). This agreement seeks to establish a national action plan aimed at addressing climate change and supporting the reduction of carbon emissions in the economy.

A reduction in Kazakhstan's carbon footprint could be achieved by substituting coal with cleaner energy sources such as natural gas and renewable energy. In addition to enhancing air quality, this transition fosters an environment conducive to attracting investments in the "green" economy.

Results

The analysis of the data revealed that the integration of renewable energy technologies in Kazakhstan's agricultural enterprises has a beneficial effect on both economic and environmental efficiency. The reduction of CO_2 emissions, alongside significant cost savings, not only enhances the resilience of agricultural enterprises but also contributes to their long-term development. Polynomial interpolation demonstrated its efficacy in forecasting data in the absence of information for specific years, while correlation and linear regression methods corroborated the positive relationship between the advancement of RES and improvements in economic performance.

Discussion

Speaking about the efficiency of the use of renewable energy sources in agriculture conducted in other countries, it can be stated that there is a high potential for reducing CO□ emissions, improving energy efficiency and energy costs. Otherwise, following the examples of Pakistan, South Korea and other countries, given the great potential of Kazakhstan in the development of solar and wind energy sources, it is possible to try to implement specific strategies for the development of the agricultural

sector related to renewable energy sources. Based on the current state of affairs, it is possible to outline in advance several initial guidelines for the constant promotion of peasant farms in the field of renewable energy sources. First of all, attention should be paid to the concept of state support, since the further continuation of subsidy and support programs in the field of renewable energy sources will promote the use of new energy-saving technologies. This applies even more to areas that have a relatively higher probability of using solar and wind energy. Secondly, it is necessary to subsidize the development of technologies by providing financing for the development of new efficient sources of renewable energy. Based on interpolation and regression methods, energy consumption and yields can be predicted to help farmers plan resource use to avoid or minimize risks that reduce farm profitability.

Conclusion

The study also suggested to increase farmers' awareness of the potential to utilize renewable energy sources, as well as to implement new energy efficient technologies. This means the need for state support in form of subsidies as well as education programs and other strategies aimed at increasing the adoption of modern technologies in agriculture.

The application of the obtained findings is within the proposal of measures and further agricultural commercialization to expand RE use in the farms with better energy performance and immune against the extrinsic economic and environmental shocks. The possibilities for further research in this direction are the investigation of economic efficiency of different types of renewable sources of energy for farms, and the creation of models of state encouragement and funding that might contribute to the implementation of sustainable technologies in the sphere of agriculture.

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