# *Economic efficiency of the GHG emissions from energy use in agriculture: comparative analysis of Ukraine and the EU member states*

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***Abstract. The article is devoted to the study of the economic efficiency of GHG emissions from the use of energy in agriculture in the EU and the candidate country for accession - Ukraine. Using the abstract-logical method, the essence of the category "economic efficiency of greenhouse gas emissions" was clarified and an indicator for its assessment was proposed. By actual statistical data and the method of economic analysis, calculations of the economic efficiency of carbon dioxide emissions from the use of energy in agriculture of the EU member states and Ukraine were made. The key factor influencing the economic efficiency of GHG emissions from energy consumption in the agricultural sector was identified. Due to econometric method of approximation estimation and the Excel software package, the presence of a direct, high-density linear relationship between energy consumption and carbon dioxide emissions in agricultural production was established. By ranking method and comparative economic analysis, a threshold value of energy consumption per hectare of agricultural land was found, which corresponds to a relatively high value gross production per ton of carbon dioxide emissions among the studied countries. It was established that for the candidate country for joining the EU - Ukraine and for the two Baltic countries - Latvia and Estonia, in order to increase the level of economic efficiency of GHG emissions in terms of implementation the European Green Deal, it is worth paying primary attention to the growth of economic productivity. Also, due to graphical and tabular methods of processing statistical data, it was established that the use of environmentally friendly energy (in particular, electric energy) in the process of agricultural production is not a key factor affecting the economic efficiency of GHG emissions.***
***Keywords: Economic efficiency, GHG emissions, agriculture, energy use, European Green Deal.***

## I. INTRODUCTION

Achieving full climate neutrality in Europe by 2050 continues to be a strategic goal within the framework of the European Green Deal. For this, the European Commission intends to reduce the GHG emission towards 50 or 55% compared with the 1990 levels [1]. This plan applies not only to transport, industry and energy sector (the largest emitters of GHG into the atmosphere), but also to agriculture. According to the general aim, the target level of carbon dioxide (equivalent) emissions in the EU's agriculture should be decreased up to 244.9 million tonnes (1.35 tonnes per hectare of agricultural land) [2].Many technological processes in agricultural

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output produce GHG emission, including the direct use of energy from various sources. Thus, the share of energy as one of the sources of GHG emission in agriculture is: for, example, in Ukraine - over 10%, while in the EU - 14% (as a share in the structure of carbon dioxide emissions directly - 22 and 37%, respectively). Moreover, these types of energy resources are mostly fossil, and therefore they are based on carbon, which is the main culprit of global climate change.

The desire to meet the criteria of climate neutrality puts agricultural producers in the EU member states and in Ukraine, as a candidate state for joining the EU, in a difficult position: to ensure the high economic potential of agricultural land use against the background of improving the quality of the environment. Under such conditions, the issue of analyzing the economic efficiency of greenhouse gas emissions from the use of energy in agriculture becomes quite relevant.

## II.MATERIALS AND METHODS

The fundamentals of the information and analytical base of the conducted study were the statistical materials of the FAO for the period 1990-2021, represented by the FAOSTAT database. The theoretical basis of the research was taken from the scientific works of Ukrainian and foreign scientists on the selected issues. The European Green Deal was the main strategic legal document for conducting this study. In turn, at the national level, the legal framework is represented by the National Energy Efficiency Action Plan for the period up to 2030 and the new strategy of the low-carbon development of Ukraine by 2050.

Among the general scientific methods for conducting the study, the following were singled out: the method of analysis, based on the essence of which the structure and algorithm of the study were constructed; the method of comparison, which made it possible to compare generalized and derived indicators of the economic efficiency of GHG emissions from the energy in agricultural production of the EU member states and Ukraine; an abstract-logical method, by which the category «economic efficiency of greenhouse gas emissions» was substantiated and the approach to its assessment was specified.

Also, the several specific scientific methods were used, particularly: the method of economic analysis and ranking to identify key factors affecting the economic efficiency of carbon dioxide emissions from energy used in the agriculture of Ukraine and Member States; the econometric method of probability approximation of data in the Excel software package to confirm the existence of a quantitative relationship between GHG and energy use in the region's agriculture; tabular and graphic methods in order to improve the analytical perception of statistical data and build correct studying conclusions.

## III.RESULTS AND DISCUSSION

According to the general scientific interpretation, efficiency is the result of activity (effect) that society, an enterprise or a person receives per unit of used (or applied) resources [3]. In turn, economic efficiency is such a ratio between resources and production results, according to which cost indicators of production efficiency are obtained [4]

It should be noted that Japanese scientists were historically the first who made an attempt to interpret the concept of economic efficiency of greenhouse gas emissions. Particularly, Kaya and Yokobori defined carbon emission efficiency as carbon productivity from a single-factor perspective. On other words, they determined the issue at a macroeconomic level as the ratio of GDP to carbon emissions in the same period [5].

In turn, Mielnik, Goldember, and Ang used carbon dioxide emissions per unit of energy consumption as an important assessment of carbon emission efficiency [6, 7]. Zaim and Taskin reviewed carbon emissions as a non-expected output variable in the field of environment. Moreover, the scientists proposed the concept of the comprehensive efficiency index, and applied this index to the OECD national research [8]. Multifactorial interpretation of the concept of «carbon emission efficiency» belongs to Ramanatha who suggested integrating it into the three frameworks of energy consumption, economic development, and, particularly, carbon emission [9]. Arjan Trinks, Machiel Mulder and Bert Scholtens define carbon efficiency as the extent to which a given level of output is produced with minimum feasible carbon emissions relative to direct sector peers [10].

However, the question of explaining the identification of GHG emissions as a resource, and not a result, remains unresolved.

As well-known, greenhouse gas (GHG) emission is the result (effect) of economic activity, in particular from the use of various types of energy. But also it is that part of the total amount of resources (including energy) used that has not been converted into useful work and transformed into a type of negative externalities (entropy). It follows that greenhouse gases (particularly, carbon dioxide) at the theoretical level can be viewed not only as an effect that is a powerful factor of climate change, but also as a modified resource that was used to create a product in the economic system. Thus, the economic efficiency of greenhouse gas emissions (in particular, carbon dioxide) can be used in the research theory and can be defined as the ratio of the economic effect in value terms (e.g., net profit, gross production value) to the amount of greenhouse gas emissions in physical units (e.g., carbon dioxide).

The study revealed that the leaders by value of agricultural production (constant prices 2014-2016) per 1 t $CO_2$ emissions from energy used in agriculture among EU member states in 2021 were Romania (10525 USD), Greece (10375 USD) and Ireland (9475 USD). It should be noted that Romania has been occupying a leading position since 2000, i.e. even before joining the EU. In turn, Ukraine, as a candidate country for EU membership, demonstrated a relatively medium level of economic efficiency of carbon dioxide emissions from energy in agriculture – 5205 USD per 1 t carbon dioxide in 2021. In contrast, the EU member states with high economic productivity of agricultural land productivity show low

economic efficiency of GHG emissions. For example, the Malta`s, Netherlands`s and Cyprus`s agricultural gross production value per 1 t $CO_2$ emissions were only 2912; 1057 and 3562 USD accordingly (fig.1).

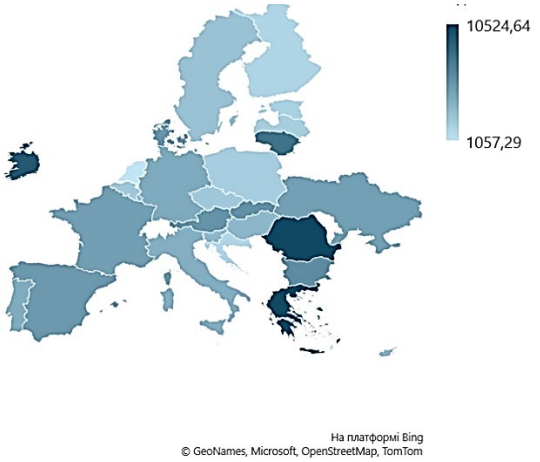


Fig. 1. Economic efficiency of GHG emissions from energy use in the EU and Ukrainian agriculture in 2021, USD per 1 t CO2 emissions
Source: complied by the authors

Obviously, the economic effect is not a determinative factor of the resulting indicator. In turn, GHG emissions are closely related to energy use. Thus, as a result of the research conducted on the basis of data from EU member states and Ukraine, it was established that there is a high level of approximation probability ($R^2$=0,95) and a direct linear relationship between energy use and carbon dioxide emissions in the process of agricultural production (fig.2). Also this conclusion was previously confirmed by Gołasa, P.; Wysoki ´ nski, M.; Bie ´nkowska-Gołasa and other scientists [11].

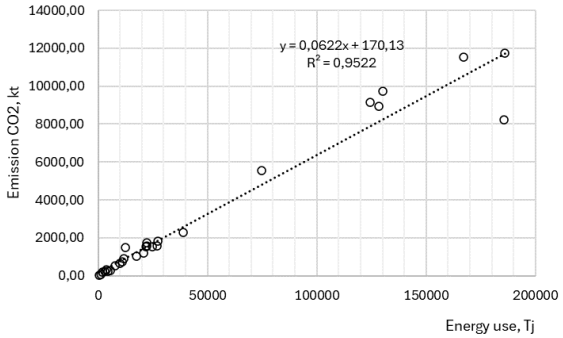


Fig.2. Quantitative relationship between carbon dioxide emissions and energy use in agriculture of EU member states and Ukraine in 2021
Source: complied by the authors

Therefore, in the countries with a high degree of economic efficiency of greenhouse gas emissions in agriculture, also high energy efficiency of production should be observed. Thus, the gross production value (constant prices 2014-2016) in agriculture per 1 terajoul of energy use in Romania was 750 thousand USD, in Greece – 1232 thousand USD and Ireland – 712 thousand USD. To compare, in Ukraine, Malta, Cyprus and Netherlands the meaning of resulting indicator were 387; 226; 379 and 73 thousand USD accordingly.

In addition, the results of the study of energy use in agricultural production of the EU member states and Ukraine indicated that gross production value per ton of carbon dioxide emission over 6000 USD was achieved by energy using volume less than 3 terajoules per 1 hectare of agricultural land (table 1). In the group of leading countries, the example of Lithuania deserves attention, because a high level of economic efficiency of carbon dioxide emissions was achieved at the expense of the lowest value of energy consumption per unit of agricultural land. The greater impact on the reduction of GHG emissions came from energy efficiency measures, which were more pronounced especially in the period from 2011 to 2013 and from 2018 to 2019, when energy intensity in Lithuania decreased significantly [12].

TABLE 1. COMPARATIVE ANALYSIS OF INFLUENCING FACTORS ON THE ECONOMIC EFFICIENCY OF GHG EMISSIONS BETWEEN THE EU MEMBER STATES AND UKRAINIAN AGRICULTURE IN 2021

| № | Country | Gross production value per 1 t $CO_2$, USD | per hectare of agricultural land | | |
|---|---|---|---|---|---|
| | | | Gross production value, USD | $CO_2$, kt | Energy use, Tj |
| 1 | Romania | 10525 | 1253 | 0,12 | 1,7 |
| 2 | Greece | 10375 | 2634 | 0,25 | 2,1 |
| 3 | Ireland | 9475 | 1944 | 0,21 | 2,7 |
| 4 | Lithuania | 7901 | 693 | 0,09 | 1,6 |
| 5 | Bulgaria | 6431 | 863 | 0,13 | 1,9 |
| 6 | Slovakia | 6046 | 979 | 0,16 | 2,9 |
| 7 | Austria | 5966 | 2423 | 0,41 | 6,7 |
| 8 | Denmark | 5750 | 3455 | 0,6 | 10,3 |
| 9 | Spain | 5611 | 1913 | 0,34 | 4,9 |
| 10 | France | 5251 | 2160 | 0,41 | 6,5 |
| 11 | Ukraine | 5205 | 700 | 0,13 | 1,8 |
| 12 | Germany | 4628 | 2721 | 0,59 | 7,8 |
| 13 | Portugal | 4521 | 1825 | 0,4 | 5,6 |
| 14 | Italy | 4301 | 3170 | 0,74 | 10,0 |
| 15 | Hungary | 3825 | 1377 | 0,36 | 5,4 |
| 16 | Slovenia | 3789 | 1366 | 0,36 | 4,9 |
| 17 | Luxembourg | 3708 | 2210 | 0,6 | 8,5 |
| 18 | Cyprus | 3562 | 5670 | 1,59 | 14,9 |
| 19 | Sweden | 3142 | 1265 | 0,4 | 6,9 |
| 20 | Malta | 2912 | 10079 | 3,46 | 44,4 |
| 21 | Belgium | 2855 | 4766 | 1,67 | 28,5 |
| 22 | Czechia | 2790 | 1381 | 0,50 | 6,3 |
| 23 | Poland | 2496 | 1414 | 0,57 | 12,8 |
| 24 | Latvia | 2469 | 643 | 0,26 | 3,8 |
| 25 | Estonia | 2222 | 755 | 0,34 | 3,7 |
| 26 | Finland | 2007 | 1342 | 0,67 | 11,0 |
| 27 | Croatia | 1971 | 1004 | 0,51 | 7,4 |
| 28 | Netherlands | 1057 | 6740 | 6,38 | 92,2 |

Source: compiled by the authors

However, Ukraine, which has almost the same energy use and GHG per hectare of agricultural land as Romania, is significantly inferior to the group leader by the economic efficiency of carbon dioxide emissions and ranks only 11th in the ranking. It means that Ukrainian agricultural producers have not been still using the available energy resources efficiently enough, creating relatively small added value per unit of energy. This reserve should be used in the process of further European integration and implementation of the European Green Deal. Also, the situation in Latvia and Estonia is also somewhat similar. Their agricultural sectors continue to be inefficient by the economic efficiency of both land use and GHG emissions, despite of low level of energy use. As a result, special attention should be paid not so much to the environmental criterion as to the development of the economic potential of agricultural production. Instead, countries with highly productive agricultural land use (primarily Malta, the Netherlands, Cyprus, and Belgium) should make significant efforts to move faster to a climate-neutral agricultural production model under the European Green Deal.

The low level of carbon dioxide emissions from energy consumption in the agriculture of European countries, which belong to the group with a high indicator of economic efficiency of greenhouse gas emissions, was achieved primarily due to ensuring high energy efficiency of production. Since the main source of energy (more than 60% in the structure of total consumption), excluding Greece, was fossil resources – petroleum products and natural gas. It is well known, that these energy sources are powerful carriers of carbon and significant pollutants of the atmosphere (fig.3). At the same time, the example of Greek agriculture can be a bright vector of the future ecological and economic transformation of the industry on the basis of the European Green Deal. In turn, the Ukrainian strategy «Energy Efficiency, Renewable Energy, Modernization and Innovation, Market and Institutional Transformation» by 2050 provides a gradual transition from the use of equipment running on diesel fuel to biodiesel [13]. Furthermore, with constant consumption, non-renewable sources of energy raw materials (oil, natural gas, coal) will be exhausted in the future [14].

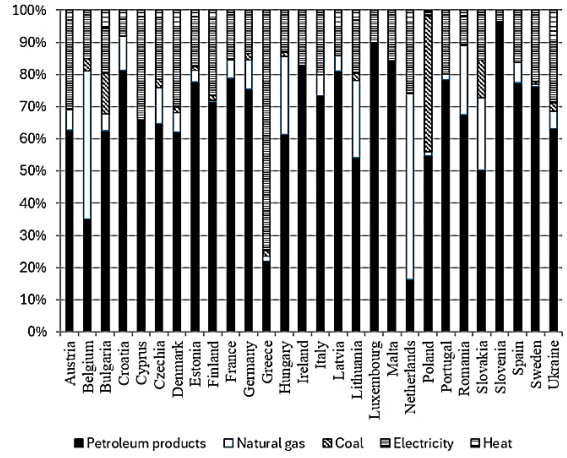


Fig.3. The structure of energy use in agriculture of EU member states and Ukraine in 2021 by types, %
Source: complied by the authors

## IV.CONCLUSIONS

1. A key indicator of the economic efficiency of GHG emissions from the use of energy in agriculture can be the ratio of the value of gross production (in constant prices of a certain period) to the volume of carbon dioxide emissions from the energy used, which was spent on the agricultural production process;
2. Among the Member States and Ukraine, the highest level of economic efficiency of GHG emissions from energy use in agriculture was achieved by those countries where there were a low level of GHG emission and energy use per hectare of agricultural land but not a high economic effect;
3. As a result of the analysis, it was found that the main factor affecting the economic efficiency of GHG emissions from the energy use in agriculture is the intensity of energy use (energy consumption per unit of land area). That is, the lower the intensity of energy use in agricultural production, the higher the economic efficiency of GHG from its consumption;
4. The presence of a close direct linear relationship between energy consumption in agricultural production and carbon dioxide emissions was clarified and confirmed.
5. It was found that the type of energy (fossil energy or electricity) that is consumed to ensure agricultural production is not a determining factor affecting the economic efficiency of carbon dioxide emissions; however, it can be a promising factor in the further advancement of European agriculture towards climate neutrality.

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