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THE INTENSITY OF GREENHOUSE GAS EMISSIONS FROM THE FOOD PRODUCTION SYSTEM IN THE VISEGRAD GROUP COUNTRIES

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ABSTRACT: Greenhouse gas emissions of anthropogenic origin, including those from the food production system, are considered one of the main reasons for global climate warming, so many measures are being taken to reduce them. After joining the European Union, the Visegrad Group countries are obliged to monitor and report the level of greenhouse gas emissions, which is also closely related to the level and structure of energy consumption. According to the International Energy Agency estimates, 75% of greenhouse gas emissions in the European Union are related to energy production or use. High food productivity brings with it energy-intensive solutions that increase emissions. It is also important that tackling climate change is not a barrier to increased food production. In this context, the lowest possible emission intensity of the food production system, understood as the amount of greenhouse gas emissions per unit of production or gross value added, should be sought. The study aimed to calculate the emission intensity of food production systems in the Visegrad countries in 2010-2016. The emission intensity of agribusiness greenhouse gases was calculated as the emissions forfeited per unit of output and gross value added. The paper uses the author's methods, which are consistent with each other, for calculating agribusiness production and income, as well as greenhouse gas emissions from the food production system. Data from input-output tables and, consistent with these tables, environmental accounts published on Eurostat's website were used to calculate these quantities. During the period under review, the GHG intensity index decreased in Visegrad countries despite an overall increase in emissions of primary greenhouse gases from food production. However, these changes are minor, mainly due to the short analysis period. However, further growth in food production may not contribute to an increase in the level of greenhouse gas emissions. Financing pro-environmental investments at all stages of food production will be key in this regard. Further research in this area, using the methodology presented in this article, will make it possible to compare the results obtained with those calculated from more recent data. This will make it possible to capture the impact of, for example, the European Green Deal and the financing of pro-environmental investments in the agribusiness of the Visegrad Group countries.

KEYWORDS: agribusiness, greenhouse gas emissions, emission intensity, Visegrad Group

Introduction

Climate change caused by global warming has become an important topic of debate among environmental economists, environmentalists, and politicians at the national and international levels. It is argued that excessive greenhouse gas (GHG) emissions are the leading cause of the environmental problem, and carbon dioxide (CO2) is considered the primary greenhouse gas contributing to global warming (Copernicus Climate Change Service, 2023; Pao & Tsai, 2011; Tang & Tan, 2015). All sectors of the economy are the source of these emissions, but the emissions generated by energy production and heating, industry, and the agro-food sector are particularly significant (Pierrehumbert, 2005). Fossil fuel combustion is responsible for about two-thirds of greenhouse gas emissions, and food production, which produces about one-quarter of greenhouse gases (26%). Agricultural production alone accounts for about 10-12% of all anthropogenic greenhouse gas emissions and continues to grow (Tubiello et al., 2014). Processing and distribution, on the other hand, account for about 1/5 of greenhouse gas emissions in the food system (Poor & Nemecek, 2018; Our World in Data, 2022). The consequences of global warming are dire, so reducing greenhouse gas emissions has become an important policy goal worldwide. This is important in the national economy and specific sectors, such as the entire food system, mainly because of the projected global population. In 2024, the earth will be inhabited by some 8.1 billion people, and it is estimated that by 2050 this number will increase by another 2 billion. Feeding such a high population without degrading the environment or contributing to global warming is already a major problem for the world, and according to forecasts, the problem will grow more and more (Baer-Narwocka & Sadowski, 2019; Fróna et al., 2019). Therefore, reducing GHG emissions must not be a barrier to increasing food production, especially with projected population growth in developing countries, where per capita food consumption will also increase. One of the main strategies to reduce GHG emissions from agriculture is to develop and implement cultivation techniques that, on the one hand, reduce environmental pressure and, on the other hand, do not reduce production efficiency (Fróna et al., 2019). Most studies conclude that reducing inputs and switching to less intensive cultivation is necessary to achieve low-carbon agriculture (Khan et al., 2017). However, some studies indicate that intensive agriculture can be environmentally sustainable (Searchinger et al., 2018).

The conclusion of research on GHG emissions and food production is that one should aim for the lowest possible emission rate per unit of output (unit of output) (Wang et al., 2019). Such an indicator in the literature is called emission intensity or carbon intensity, which is related to the concept of carbon footprint, which in its general form implies that the carbon footprint is a certain amount of greenhouse gas emissions that are associated with a given activity, such as production (Zhao et al., 2012). Thus, the lower the emission intensity of food production system, the fewer emissions per unit of production. In turn, inverting this indicator yields an indicator of the environmental efficiency of food production. To date, studies on emission intensity have mainly focused on comparing the performance of different cropping systems in the case of crop production (de Jesus Pereira et al., 2021; Gao et al., 2021; Gkisakis et al., 2020) or farming systems in the case of livestock production (Clark & Tilman, 2017). In the European Green Deal (European Commission, 2020) emphasises that food production reduces natural resources and pollutes the environment. Therefore, it is important to make changes in this area, such as modernising agricultural practices and increasing the share of organic farming to 25% of the total agricultural land in the EU by 2030. All these actions show how important the problem of climate change is and how much the food sector contributes to it. Its goal is to create a modern, resource-efficient economy that is climate-neutral and in which economic growth is decoupled from the use of natural resources (European Commission, 2020). Therefore, considering the previously mentioned issues, agribusiness production's energy efficiency must be improved to transform the EU economy effectively. However, official statistics do not include data on the entire agribusiness system, making monitoring progress in this area difficult. To effectively deal with this challenge, studying and controlling the amount of emissions in this sector of the national economy is necessary. One example is the research in the Visegrad countries. These countries are characterised by higher energy consumption, lower energy efficiency and low levels of investment (Śmiech & Papież, 2014), which significantly impacts the level of greenhouse gas emissions into the atmosphere. One reason for this is that these countries have historically invested in energy-intensive heavy industry and focused on cheaper energy sources such as coal and oil (Naudé et al., 2019; Strauss et al.,

DOI: 10.34659/eis.2025.92.1.1066

2016). Through this type of research, it is possible to indicate how these countries are coping with reducing greenhouse gas emissions from agriculture and the overall food production system. The overall level of emissions from specific spheres of agribusiness and the national economy will be studied. In the context of the study of these quantities, it is important to relate gas emissions to GDP, as well as global production in agribusiness and the entire national economy (intensity and efficiency).

The study's purpose is to calculate the emission intensity of food production systems in the Visegrad Group countries. Emission intensity is understood as the emissions of the main greenhouse gases associated with food production per unit of this production. The analysis was carried out for two periods: 2010-2012 and 2014-2016.

The remainder of the article is divided as follows: Section 2 presents the data used and the research methods employed; Section 3 contains the research results and their discussion; Section 4 summarises the analysis.

Metodology

The statistical data used in the article comes from three sources: Full international and global accounts for research in input-output analysis (FIGARO) (Rémond-Tiedrez & Rueda-Cantuche, 2019), World Input-Output Database (WIOD) Environmental Accounts Update 2000-2016 (Corsatea et al., 2019), and FAOstat emission data (NDC Partnership, 2024).

The FIGARO input-output tables include data on cash flows between the 64 sectors of the economies of the European Union member states and the United Kingdom and the United States, as well as data on the cash flows of the EU's other major trading partners (Argentina, Australia, Brazil, Canada, Switzerland, China, Indonesia, India, Japan, Republic of Korea, Mexico, Norway, Russian Federation, Saudi Arabia, Turkey, South Africa). The tables also include modelled flow data for the rest of the world. The FIGARO tables were created in cooperation between Eurostat and the Joint Research Centre of the European Commission. In the May 2021 version, they cover the years 2010-2017 (data for 64 economic sectors) and 2018-2019 (data for 21 economic sectors).

The WIOD Environmental Accounts Update 2000-2016 database, also created by the Joint Research Centre of the European Commission, includes carbon dioxide ($CO_{2)}$ emissions data from 56 economic sectors for 40 countries worldwide, including all EU countries. To ensure compatibility of FIGARO data with WIOD data, the former was aggregated from 64 to 56 economic sectors, as in WIOD Environmental Accounts data. The period 2010-2016 was analysed, as these are the years for which the available statistics in WIOD and FIGARO overlap.

Complementing the information on greenhouse gas (GHG) emissions from the food production system was FAO data on farm-gate emissions of methane (CH_4) and nitrous oxide (N_2O). It is these two gases that account for the largest portion of GHG emissions from agriculture into the atmosphere (Han et al., 2019). The intensity of GHG emissions was determined by the volume of emissions, expressed in CO_2 equivalent, and the economic size of the food production system, i.e. its GDP and output. The determination of these volumes was made using data from FIGARO input-output tables.

In the calculations carried out, it is assumed that the food production system consists of all food production operations taking place in agriculture and the food industry, as well as the accompanying services and materials used that are obtained from other sectors of the economy. Ultimately, therefore, the food production system can be divided into 3 aggregates: I – supply, which consists of those parts of the sectors that provide agriculture and the food industry with the materials and services needed to produce food; II – agriculture; III – the food industry. The sum of all aggregates constitutes the size of the food production system. In practice, the determination of the size of aggregate I – supply, is possible by using the properties of input-output tables, using the assumptions of life cycle analysis. Thus, the food production system understood in this way does not include, in its scope, food supply, and focuses only on the production sphere. Therefore, the system boundary is set at the food industry activity level.

Based on the International Standard Industrial Classification, Revision 4 (ISIC Rev. 4), it was found that the sectors that corresponded most closely to agriculture and the food industry in turn were sector A01: Crop and animal production, hunting, and related service activities, and sector

DOI: 10.34659/eis.2025.92.1.1066

C10-C12: Manufacture of food products, beverages, and tobacco products. To calculate the output of the food production system, the output of its individual aggregates was calculated. The calculation of aggregate one's output consisted of adding up the intermediate consumption of agriculture and the food industry and subtracting the amount of self-supply to avoid double-counting error, as follows:

$$O_I = IC_a + IC_f - z_{aa} - z_{ff}, \tag{1}$$

where:
O_I – aggregate output of aggregate one,
IC_a – intermediate consumption in agriculture,
IC_f – indirect consumption in the food industry,
z_{aa} – self-supply of agriculture,
z_{ff} – self-supply of the food industry.

The value of the output of aggregate two was calculated as the difference between the output of agriculture and the value of food industry supply by agriculture, as this value was included in aggregate one:

$$O_{II} = O_a + z_{af}, \tag{2}$$

where:
O_{II} – aggregate output of the second aggregate,
O_a – agricultural output,
z_{af} – supply of food industry by agriculture.

Using the same assumption, the aggregate output of the third aggregate was calculated. The value of the food industry's supply to agriculture was subtracted from the food industry's output:

$$O_{III} = O_f + z_{fa}, \tag{3}$$

O_{III} – aggregate output of the third aggregate,
O_f – food industry output,
z_{fa} – supply of agriculture by the food industry.

Using a similar technique, the GDP of the food production system was determined. First, it is necessary to determine the value added in purchasers' prices for each sector of the economy, which according to the System of National Accounts is the sum of value added in basic prices and taxes on net products:

$$VA_{PP} = VA_{BP} + NT_{OP}, \tag{4}$$

where:
VA_{PP} – value added at producer prices
VA_{BP} – value added at base prices,
NT_{OP} – taxes on net products.

To calculate the value of the GDP of the first aggregate, it is necessary to determine what proportion of the GDP of the various sectors of the economy it consists of. For this purpose, the coefficients of the flow of value added from each sector were determined:

$$CVA_i = VA_{PPi}/O_i \tag{5}$$

where:
CVA_i – value-added flow factor for the sector,
VA_{PPi} – value added of sector *i* at producer prices,
O_i – output of sector *i.*

Then, the determined coefficients were multiplied by the value of the flow of products and services from the respective sectors to agriculture and the food industry, which were taken from the

DOI: 10.34659/eis.2025.92.1.1066

input-output table. Accordingly, the GDP of each aggregate of the food production system was determined as:

$$GDP_I = \sum_{i=1}^{n}(z_{ia} * CVA_i) + \sum_{i=1}^{n}(z_{if} * CVA_i) - (z_{aa} * CVA_a) - (z_{ff} * CVA_f), \tag{6}$$

where:
GDP_I – GDP aggregate one,
z_{ia} – flow from the sector *and* into agriculture,
z_{if}– flow from *i* sector to food industry.

$$GDP_{II} = VA_{PPa} - z_{af} * CVA_a \tag{7}$$

where:
GDP_{II} – second aggregate *GDP,*
VA_{PPa} – agricultural value added at producer prices.

$$GDP_{III} = VA_{PPf} - z_{fa} * CVA_f, \tag{8}$$

where:
GDP_{III} – gross domestic product of agribusiness aggregate III,
VA_{PPf} – food industry value added at producer prices.

In the next step, CO_2 emissions from the food production system were calculated using a similar procedure to the one used to determine GDP. In the first step, carbon footprint factors (CO_2 emissions) were calculated for each sector, using emissions data from WIOD Environmental Accounts and cash flow data from FIGARO input-output tables:

$$CCF_i = E_{CO2i} / O_i, \tag{9}$$

where:
CCF_i – carbon footprint coefficient of sector *I,*
E_{CO2i} – CO_2 emissions of sector *i.*

The calculated carbon footprint coefficients were multiplied by the respective values of cash flows to agriculture and the food industry for each economic sector, similar to the calculation of GDP. Finally, the value of CO_2 emissions from the food production system was calculated using the formula:

$$FPE_{CO2} = \sum_{i=1}^{n}(z_{ia} * CCF_i) + \sum_{i=1}^{n}(z_{if} * CCF_i) - (z_{afa} * CCF_a) - (z_{faf} * CCF_f) + AE_{CO2} + FIE_{CO2}, \tag{10}$$

where:
FPE_{CO2} – CO_2 emissions from food production system,
z_{afa} – total input value of agriculture sector *a* to the food industry and agriculture,
z_{faf} – total input value of food industry sector *f* to agriculture and the food industry,
AE_{CO2} – CO_2 emissions from agriculture,
FIE_{CO2} – CO_2 emissions from the food industry.

GHG emissions from the food production system were then calculated by adding CH_4 and N_2O emission values from agriculture, which were obtained from the FAO database, to the carbon footprint results:

$$FPE_{GHG} = FPE_{CO2} + AE_{CH4} + AE_{N2O}. \tag{11}$$

where:
FPE_{GHG} – GHG emissions from food production system,
AE_{CH4} – CH_4 emissions from agriculture,
AE_{N2O} – N_2O emissions from agriculture.

Using the above calculations, it is possible to determine the emissions intensity of a food production system based on the quotient of its greenhouse gas emissions and the value of its GDP or output.

Results and discussion

Agribusiness greenhouse gas emissions

Since the establishment of the European Union, many strategies and programs have been adopted to increase energy efficiency and reduce greenhouse gas (GHG) emissions in food production systems (Masi et al., 2021). The goal is to create a low-carbon economy that can significantly contribute to climate change mitigation (Yan et al., 2017). When analysing the Visegrad Group (V4) countries, it is important to keep in mind that they only joined the European Community in 2004 and thus had a more difficult task in adapting to current standards, if only because they were poorer and less developed countries, especially compared to the EU-15 (Schmidt, 2016). Additionally, with the weaker agricultural production performance of V4 countries (Szabo et al., 2018) affecting the entire food system, the challenge was to reduce GHG emissions while developing food systems. Among the V4 countries, Poland was the largest emitter of carbon dioxide (CO_2) during the period analysed, accounting for almost 80% of CO_2 emissions from agribusiness in the group of countries studied. The reason for such a significant amount of CO_2 emissions from Polish agribusiness was, among other things, its dependence on fossil fuels, the combustion of which contributes significantly to GHG emissions, and is used directly to power machinery and produce mineral fertilisers (Gołasa et al., 2021). Moreover, Poland, compared to the other countries analysed, was characterised by greater agricultural production and a larger share of agribusiness in the economy, which was also reflected in the amount of CO_2 emissions (Figure 1). In addition, Poland is one of the largest emitters of CO_2 in the EU due to emissions from organic soils (ECA, 2021). During the analysed period, Poland reduced its CO_2 emissions, which was responsible for a significant reduction in emissions in the supply phase, by more than 0.5 million tons, and by almost 0.5 million tons in agriculture.

Agribusiness also accounted for a relatively large share of Hungary's economy, but CO2 emissions were significantly lower in this case. The country was far less dependent on fossil fuels and had a larger share of renewable energy sources in food production systems (Bajan et al., 2021), which resulted in far lower CO_2 emissions. The importance of renewable energy sources in food production systems for environmental protection was also pointed out by Aydoğan and Vardar (2020) in their study.

It is also important to note that the intensity of GHG emissions from agriculture is determined by various factors, such as air temperature, soil properties, and agricultural practices used, making it possible to observe significant differences in the amount of emissions depending on the analysed country (Mrówczyńska-Kamińska et al., 2021). In the case of Hungary, an increase in CO_2 emissions was observed during the analysed period, mainly through an increase in emissions from agriculture, from 1.5 million tons in the 2010-2012 period to more than 2 million tons in the 2014-2016 period. This was accompanied by a decrease in the area of agricultural land, as confirmed by data from the Food and Agriculture Organisation of the United Nations (FAO). However, given the growing population and the resulting need to produce more food, coupled with declining agricultural land, this often results in more intensive use of the land we have and even more pressure on the environment (Creutzig et al., 2019). A slight increase in CO_2 emissions in agribusiness has also been observed in the Czech Republic. However, unlike in Poland and Hungary, the supply of inputs to the food system there accounted for the largest share of emissions and was responsible for more than 2 million tons of CO_2 emissions in both periods analysed, accounting for more than 40% of Czech agribusiness emissions. Slovakia, on the other hand, saw the smallest CO_2 emissions among the countries analysed. Slovak agribusiness contributes little to the economy; additionally, in comparison with the other

DOI: 10.34659/eis.2025.92.1.1066

countries, Slovakia has the smallest agricultural production, which is reflected in the fact that it is the smallest, in absolute terms, emitter in the V4 group of countries.

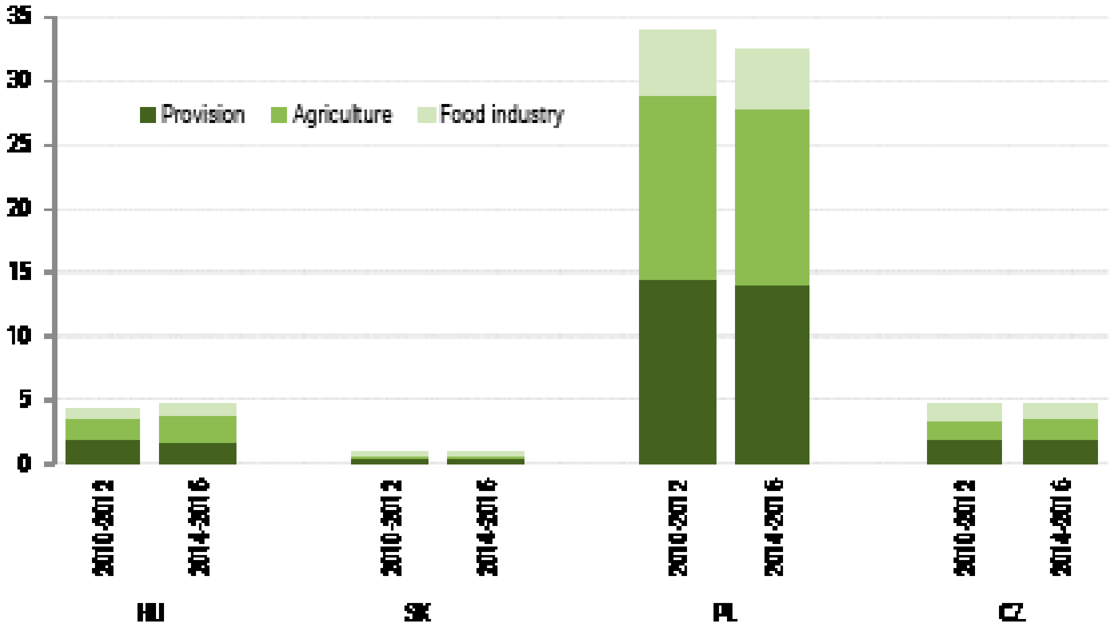

Figure 1. Agribusiness carbon emissions in selected countries (megatons)

Source: authors' work based on WIOD (2016), Remond-Tiedrez and Rueda-Cantuche (2019) and NDC Partnership (2024).

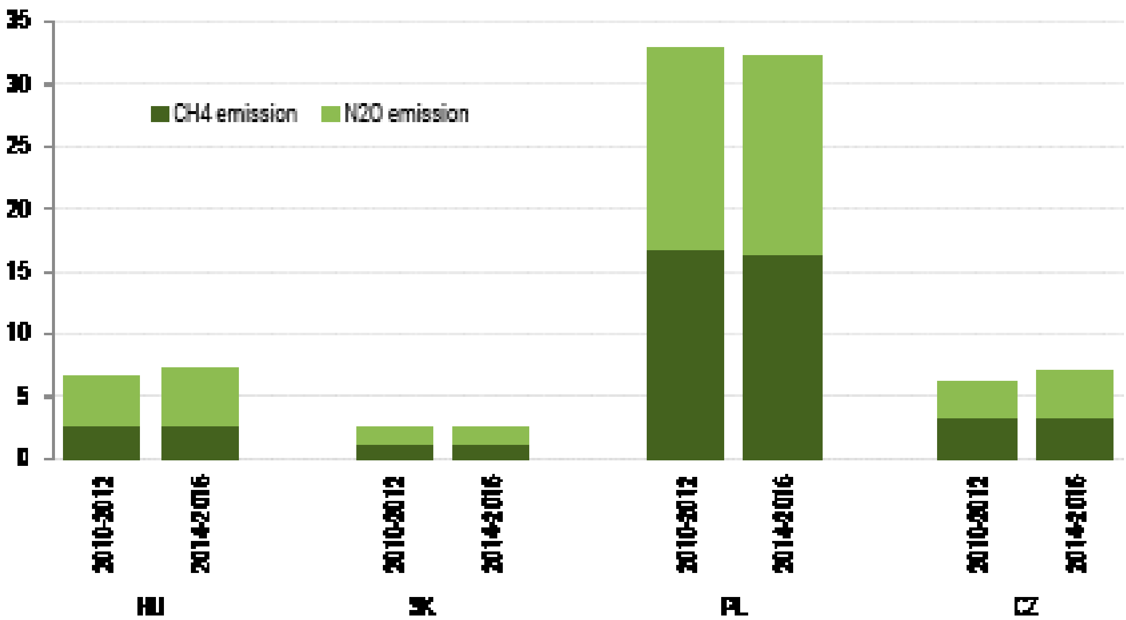

Figure 2. Agricultural emissions of methane and nitrous oxide in selected countries in megatons of carbon dioxide equiva-lent

Source: authors' work based on NDC Partnership (2024).

In addition to CO_2, significant gases emitted from food production systems are nitrous oxide (N_2O) and methane (CH_4), which mainly result from crops and livestock farming (Camanzi et al., 2017). As with CO_2, Poland was the largest emitter of CH_4 and N_2O (Figure 2). According to Poland's National Inventory Report (2018), enteric fermentation was the main source of CH_4 emissions in Polish agriculture, while land use and manure management accounted for the largest share of N_2O emissions. The decrease in these emissions over the period analysed was due to a decline in livestock populations, as observed by Harsányi et al. (2021). This is also confirmed by detailed FAO data, which shows that between 2010 and 2016, CH_4 emissions in Poland from enteric fermentation decreased by 3%, while those from manure management decreased by almost 14%. For manure management, a 9% reduction in N_2O emissions was also observed. However, the reduction in N_2O emissions from manure management was accompanied by an increase in emissions due to the use of synthetic fertilisers. In Poland, the increase was relatively small, amounting to 5% over the analysed period.

The opposite situation occurred in the other V4 countries. Both Hungary, the Czech Republic and Slovakia saw an increase in N_2O emissions, where the main reason was a significant increase in emissions from the use of synthetic fertilisers, by almost 30% in Hungary, 70% in the Czech Republic and 35% in Slovakia. CH_4 emissions, on the other hand, although they were at a significantly lower level than in Poland, enteric fermentation and manure management were also major sources. In addition, emissions from enteric fermentation increased by about 5% in Hungary and the Czech Republic during the period analysed, resulting in an overall increase in CH_4 emissions, while they decreased by 5% in Slovakia, which in turn translated into an overall decrease in emissions.

With the observed differences in GHG emissions from agribusiness, attention should be paid not only to differences in production directions or soil properties. Also important, from the point of view of reducing emissions and improving environmental performance, are the technological improvements that are needed (Abbas et al., 2020). Garnett (2011) also pointed out that the observed population growth and significant consumption of meat and dairy products, the production of which contributes significantly to GHG emissions, may be so strong that technological changes will not be sufficient to reduce emissions. In this context, it is important to focus on other factors contributing to GHG emissions, such as human nutrition and consumption patterns. In the case of European countries, consumption patterns were highlighted by Baer-Nawrocka and Sadowski (2019), who observed changes in food consumption moving toward a diet less dependent on animal products. According to Popp et al. (2010), this should be considered an important element in addition to the desirable technological changes supporting emission reductions, as changing consumption patterns can also contribute to reducing GHG emissions from food production systems.

Indicators of agribusiness emissions

In the case of the V4 Group countries, the volume of CO_2, N_2O and CH_4 emissions was reflected in the size of agribusiness emission factors, which represent the ratio of emission volume to GDP (Figure 3) and the ratio of emission volume to output (Figure 4). However, in the case of emissivity ratios, the differences between the analysed countries are much smaller compared to the total amount of emissions from agribusiness. Among the countries studied, Poland had the highest emissivity, where the highest emission intensity per unit of GDP was observed in agriculture. This is a result of significant GHG emissions from agriculture, with a relatively small contribution of agriculture to agribusiness GDP, which was also observed in the other V4 countries. In the case of Poland, this indicator decreased during the period under review, as did emissions per unit of output. A similar situation occurred in Slovakia, where a decrease in the analysed emissivity indicators was observed. It is important to note, however, that in the case of emissions per value of output, the ratio is decreasing at a slower rate than the emission ratio per GDP. In addition, in Hungary and the Czech Republic, despite the decrease in emissions/GDP, emissions per unit of output increased. This is because during the period under review, the rate of growth of output, determined by the amount of intermediate consumption, i.e. inputs used in the production process, was significantly lower than the rate of growth of GDP. The slower rate of growth of output compared to GDP and the reduction in the emission factors in Poland and Slovakia should be considered a positive phenomenon, as it indicates an increase in the profitability of food production systems and a reduction in their material intensity.

In the case of Poland, analysing the various spheres of agribusiness, an increase in the share of the food industry in GDP and a decrease in the share of the supply sphere and agriculture were observed. An analogous situation occurred in the case of the structure of output. The most profitable sphere of agribusiness in Poland was supply, but in the analysed period, the most dynamic growth was observed in the food industry, which indicates its development and increasing profitability. Taking this into account, it can be concluded that it was the development and increased profitability of the food industry which influenced a significant reduction in the emission factors. Due to the fact that the food industry is considered to be quite material-intensive in agribusiness (Bajan & Mrówczyńs-

DOI: 10.34659/eis.2025.92.1.1066

ka-Kamińska, 2020), which is also confirmed by data for Poland, the reduction in emissions rates in this case may be due to technological changes in the food production system. Schneider and Smith (2009) and Senyolo et al. (2018), among others, have highlighted the role of technological innovations in food production to reduce the carbon intensity of food production systems.

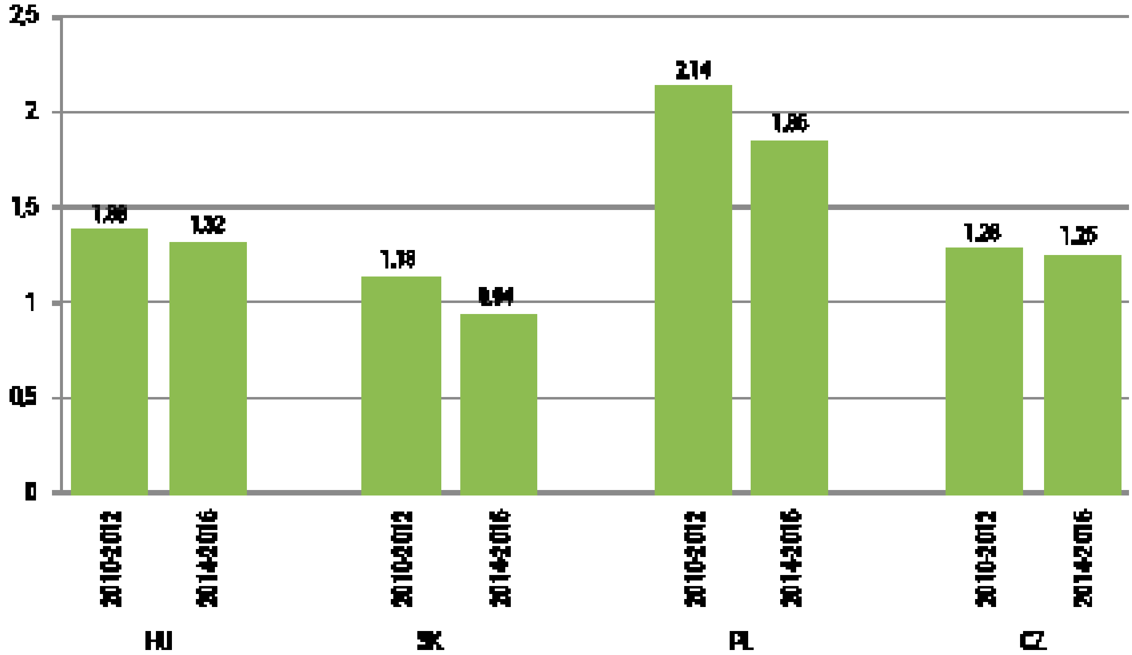

Figure 3. Agribusiness carbon footprint per agribusiness GDP (kilogram of CO2 equivalent/euro 1 worth of GDP)
Source: authors' work based on WIOD (2016), Remond-Tiedrez and Rueda-Cantuche (2019) and NDC Partnership (2024).

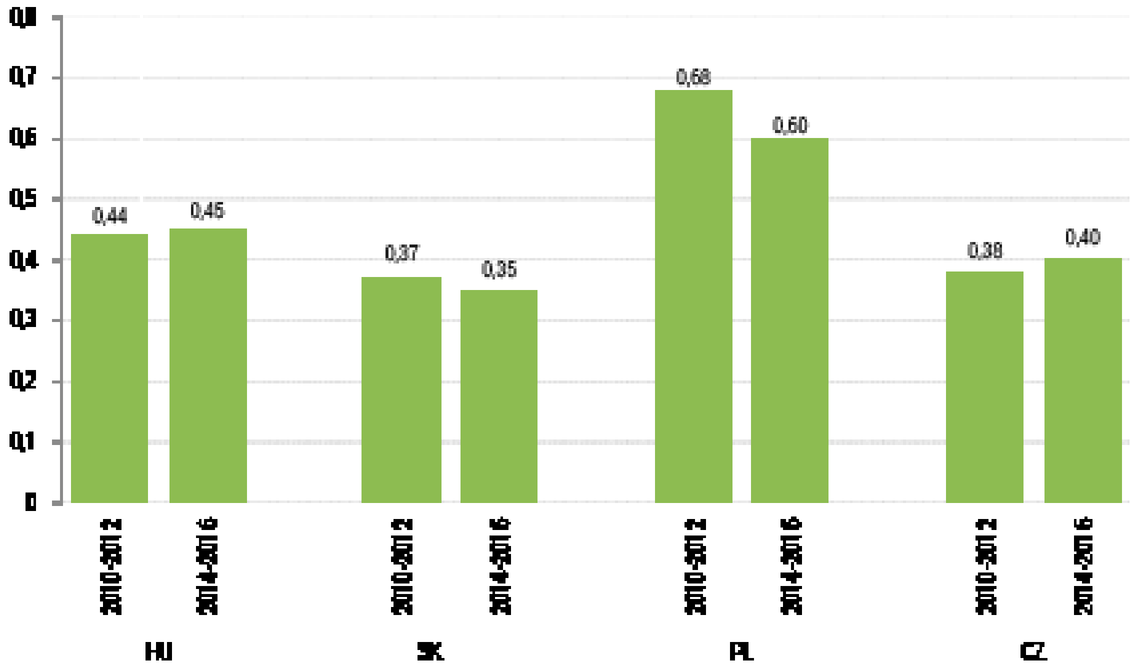

Figure 4. Agribusiness carbon footprint per agribusiness global production (kilogram of CO2 equivalent/euro 1 worth of global production)
Source: authors' work based on WIOD (2016), Remond-Tiedrez and Rueda-Cantuche (2019) and NDC Partnership (2024).

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The opposite situation occurred in the other V4 countries. Both Slovakia, the Czech Republic and Hungary saw an increase in the share of agriculture in the GDP structure and output, and a decrease in the share of the food industry. In the case of Slovakia, where the emissivity rates decreased, the most profitable sphere of agribusiness was indicated, indicating its low material intensity. It should also be kept in mind that Slovakia had the smallest agricultural production in the V4 Group of countries, which explains the low material intensity of agriculture. The relationship between the volume of agricultural production and material intensity was also pointed out by Baer-Nawrocka and Mrówczyńska-Kamińska (2019). A similar situation in the structure of agribusiness was observed in the Czech Republic, but there, the highest profitability was characterised by the sphere of supply, and in addition, total emissions significantly increased during the analysed period, which was reflected in an increase in the carbon intensity of food production systems. In the case of Hungary, on the other hand, total emissions from agribusiness increased during the period under analysis; in addition, a relatively small increase in the profitability of agribusiness was observed, which increased the indicator representing the ratio of emissions to output. In the case of Hungary and the Czech Republic, the increase in the ratio of emissions per output and the relatively small decrease in emissions/GDP also indicate how carbon-intensive the structure of inputs used in the production process is. Therefore, reducing GHG emissions from agribusiness and improving environmental performance should focus on reducing inputs and reducing the material intensity of the various spheres of agribusiness, as also pointed out by Khan et al. (2017).

In the context of creating low-carbon economies, it is also important to note that in the V4 Group countries, except Poland, total GHG emissions from agribusiness have increased, and despite this, GHG emissions per GDP have decreased, which means that it is possible to increase the environmental performance of food production even while increasing emissions from agribusiness. In addition to this, given that the V4 Group countries are characterised by high economic growth rates (Gillman, 2021), the reduction in emission factors could be considered in the context of the non-linear relationship between CO_2 emissions and the change in GDP, which is an assumption of the Kuznets Environmental Curve (Stern et al., 1996).

Conclusions

The study assumes that the food production system consists of agriculture, the food industry, and all those parts of the other sectors that provide production inputs and services to agriculture and the food industry. The analysis of the greenhouse gas emission intensity index showed that in the V4 Group countries, despite the increase in greenhouse gas emissions from agribusiness, emissions per unit of gross value added and output decreased. The changes were slow due to the too-short analysis period caused by the lack of comparable data. However, these results indicate that it is possible to improve the environmental performance of food production in the countries analysed in the future, even with increased emissions from agribusiness due to increased food production. However, investments that increase environmental efficiency should be an essential element of development strategies in agribusiness, both in the analysed countries and in all countries of the European Union. This primarily involves investments in modern technologies, machinery and equipment, and renewable energy sources. An essential issue in this regard is the financing of these investments. Agribusiness in the Visegrad countries will not be able to finance all the investments independently, making it possible to meet the environmental requirements assumed in the EU plans. The financing of modern technologies and renewable energy sources will probably make it possible to significantly reduce greenhouse gas emissions, mainly from agriculture and the entire food system in the countries of Central and Eastern Europe, which are characterised by less modern equipment in means of production and production services (Szuba-Baranska et al., 2020). The level and quality of capital equipment are key determinants of changes in agribusiness GHG intensity. The availability of more recent data from input-output tables and environmental accounts depicting dependencies in this sector and the sector's linkage to the environment is a key aspect to expand future analysis related to the level of GHG emissions and their intensity across agribusiness in the countries studied. Further research in this area, using the methodology presented in this article, will allow a comparison of the results obtained with those calculated from more recent data. This will make it possible to capture the impact of, for

DOI: 10.34659/eis.2025.92.1.1066

example, the European Green Deal and the financing of pro-environmental investments in the agribusiness of the Visegrad Group countries.

Acknowlegements

The publication was financed by the Polish Minister of Science and Higher Education as part of the Strategy of the Poznan University of Life Sciences for 2024-2026 in the field of improving scientific research and development work in priority research areas.

The contribution of the authors

Conceptualisation, A.M.-K. and B.B.; literature review, A.M.-K. and B.B.; K.M. and J.Ł.; methodology, A.M.-K. and B.B.; formal analysis, A.M.-K., B.B. and J.Ł.; writing, A.M.-K., B.B. and J.Ł.; conclusions and discussion, A.M.-K., B.B. and J.Ł.

The authors have read and agreed to the published version of the manuscript.

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INTENSYWNOŚĆ EMISJI GAZÓW CIEPLARNIANYCH Z SYSTEMU PRODUKCJI ŻYWNOŚCI W KRAJACH GRUPY WYSZEHRADZKIEJ

STRESZCZENIE: Emisja gazów cieplarnianych pochodzenia antropogenicznego, w tym z systemu produkcji żywności jest uważana za jeden z głównych powodów globalnego ocieplenia klimatu, dlatego podejmuje się wiele działań w celu jej ograniczenia. Państwa Grupy Wyszehradzkiej po wejściu do Unii Europejskiej mają obowiązek monitorowania i raportowania poziomu emisji gazów cieplarnianych, co jest również ściśle związane z poziomem i strukturą zużycia energii. Według estymacji International Energy Agency 75% emisji gazów cieplarnianych w Unii Europejskiej związane jest z produkcją lub użyciem energii. Wysoka produktywność żywności niesie za sobą energochłonne rozwiązana, które zwiększają emisje. Istotne jest również to, aby przeciwdziałanie zmianom klimatycznym nie stanowiło bariery dla wzrostu produkcji żywności. Należy sądzić, że w tym kontekście powinno dążyć się do jak najmniejszej emission intensity of food production system, rozumianej jako ilość emisji gazów cieplarnianych przypadająca na wartość produkcji czy wartości dodanej brutto. Celem badania była kalkulacja intensywności emisji gazów cieplarnianych z systemu produkcji żywności w krajach Grupy Wyszehradzkiej w latach 2010-2016. Intensywność emisji gazów cieplarnianych w agrobiznesie obliczono jako wielkość emisji przepadająca na jednostkę produkcji globalnej i wartości dodanej brutto. W pracy posłużono się autorskimi, spójnymi ze sobą, metodami obliczania produkcji i dochodów agrobiznesu oraz emisji gazów cieplarnianych z systemu produkcji żywności. Do obliczeń tych wielkości wykorzystano dane z tabel input-output oraz spójnych z tymi tabelami, rachunków środowiskowych publikowanych na stronach Eurostatu. W badanym okresie w krajach Grupy Wyszehradzkiej pomimo ogólnego wzrostu poziomu emisji głównych gazów cieplarnianych z produkcji żywności zmniejsza się wskaźnik intensywności emisji gazów cieplarnianych. Zmiany te jednak są niewielkie, głównie ze względu na zbyt krótki okres analizy. Jednak jest szansa, że dalszy wzrost produkcji żywności nie będzie przyczyniał się do wzrostu poziomu emisji gazów cieplarnianych. Kluczowe w tym zakresie będzie finansowanie inwestycji prośrodowiskowych na wszystkich etapach produkcji żywności. Dalsze badania w tym zakresie, przy wykorzystaniu metodyki zaprezentowanej w niniejszym artykule, pozwolą na porównanie uzyskanych wyników z wynikami obliczonym na podstawie nowszych danych. Dzięki temu będzie możliwe uchwycenie wpływu np. Europejskiego Zielonego Ładu i finasowania inwestycji prośrodowiskowych w agrobiznesie krajów Grupy Wyszehradzkiej.

SŁOWA KLUCZOWE: agrobiznes, emisje gazów cieplarnianych, intensywność emisji, Grupa Wyszehradzka