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Lívia Benita Kiss

Development of Energy Consumption in Agriculture in the European Union between 2010 and 2021

Forecast Until 2025

Summary

Agriculture is the basis of national economic and social development, and the sector's energy consumption is an important part of the energy system. This study examines the energy consumption, agricultural production and energy consumption of the sector in the 27 countries of the European Union with a time series analysis, making a forecast until 2025.

Between 2010 and 2022, agricultural production in the European Union increased by 19% from 2021 to 2022. Both primary (by 13.5 million tonnes of oil equivalent, by 0.98%) and final energy consumption (by 5.15 million tonnes of oil equivalent, by 0.52%) decreased in the examined period. On the other hand, the energy consumption of the agricultural sector increased (by 258.1 thousand tonnes oil equivalent, 0.96%) and will continue to increase based on the forecasts. Thus, with the increase in agricultural production, the sector's energy use has increased, even though the EU's energy consumption has decreased.

Journal of Economic Literature (JEL) codes: C53, O13, Q47
Keywords: EU-27, energy consumption, agriculture

Introduction and Literature Review

Agriculture is an important basis for national economic and social development, and its energy consumption is an important part of the energy system (Zhang et al, 2023).

Dr. Lívia Benita Kiss, Hungarian University of Agriculture and Life Sciences, Georgikon Campus; Institute of Agricultural and Food Economics (kiss.liva.benita@uni-mate.hu)

About one third of global energy is consumed by the agricultural and food sectors. Energy is needed at all levels of the food value chain, including the production of agricultural inputs, field agricultural production, food processing, transportation, marketing, trade and consumption. Primary agriculture consumes only 20%, while food processing, including transportation, consumes about 40%, thereby contributing significantly to global energy consumption along agricultural value chains (FAO, 2011).

This study examines the agricultural production and energy consumption of the sector in the 27 countries of the European Union with a time series analysis, making a forecast until 2025.

In the last decade, the world's energy demand has shown a continuously increasing trend due to population growth, industrialization, technological development and urban development, which has exerted significant pressure on energy production, energy security, pollutant emissions, and climate change (Zheng et al., 2024).

Agriculture is a specific sector that supplies the food industry with raw materials. Agricultural production is a vital sector related to GHG (greenhouse gas) emissions, thereby contributing to climate change. GHG emissions from agriculture, forestry and other land use account for 22% of global GHG emissions (Svensson et al., 2021). Due to the nature of production, both agriculture and the entire agri-food sector emit a large amount of GHG (Pierrehumbert, 2005), having a significant impact on climate change (Loayza et al., 2012).

According to Sadowski et al. (2024), in order to produce enough food to supply the population, a stable climate that provides suitable conditions is also necessary. At the same time, the ever-increasing population of the world is forcing agricultural production and, consequently, GHG emission to increase. Solutions must be found that allow for ever-increasing production without further pressure on the environment and climate.

The growing population is therefore a key factor that determines the growth of agricultural GHG emissions. The population of EU-27 increased to 448,387,872 people by 2023 from nearly 440.7 million people in 2010 (Eurostat, 2023a). However, there are differences with regard to agricultural GHG emissions, which are determined by the location of the country, the efficiency of its resource utilization, and the abundance of its resources. Regardless of its cause, all climate change ultimately has significant impacts on the global ecosystem (Hu et al., 2022).

Importance of Agriculture

There is no country in the world where they do not cultivate land or engage in agriculture. Above all, agriculture is the basis of economic development in every country, so its economic importance is undisputed (APSBB, 2023).

Agricultural production is a fundamental element of the world economy, providing food and raw materials for various industries. The sector is also a significant employer, providing work and livelihood to millions of people worldwide. Agricultural production is also key to food security, as it ensures that people have access to safe and nutritious food. As the world's population is expected to reach 9.7 billion people by 2050 (United Nations, 2022), the dem-

and for food is expected to increase significantly. Agricultural production will play a critical role in meeting this demand, which in turn requires significant energy (see: Development of agricultural energy consumption in the EU chapter).

Material and Method

This study examines the evolution of the energy consumption of the 27 member states of the European Union, as well as the production of the agricultural sector and the energy consumption of the sector between 2010 and 2021, based on Eurostat data, with a time series analysis, making a forecast until 2025. This chapter was prepared based on the work of Horváthné Csolák (2023).

Time Series Analysis: Forecasting

Average Absolute Change

The average absolute change gives the average change per period, calculated using the following formula:

$$\overline{D} = \frac{\sum_{i=1}^{n} D_i}{n} = \frac{y_n - y_0}{n}$$

In the first half of the formula, the D_i denotes the change from the previous year, and the empirical variables are denoted by y, y_n is the last, y_0 is the first one of the data of the time series, and *n* is the number of periods representing the change.

Average Relative Change

The average relative change gives the average rate of change in percentage. Formula:

$$1 = \sqrt[n]{\prod_{i=1}^{n} 1_i} = \sqrt[n]{\frac{y_n}{y_0}}$$

Filtering Out Trend Effects Using the Moving Average Method

In the case of an odd number of terms "k", the series of moving averages with k terms calculated from the time series y_t (t = 1, 2, ..., n) lasts from the period t = j+1 to the period t = n-j, where j = (k-1)/2. The moving average assigned to the t-th period:

$$\hat{y}_t^{(k)} = \frac{1}{k} \sum_{i=k-j}^{t+1} y_i$$

where k: the number of members of the moving averages.

In the case of an even number of members, the period characterized by the moving average always falls between two originally specified periods. The trend values are assigned to the middle period (time point) of the corresponding section. We help in this situation by

introducing another operation, known as the alignment or centring. Alignment to the centre is done by averaging the calculated moving averages in pairs, that is, a new series of two-term moving averages is calculated. These trend values already apply to the specified period.

Methods of Forecasting

We can choose from a number of simple and complex procedures, both for estimating the near future and for prognosticating distant events. The common feature of the methods is that they start from the data of the past and the present and project the experience into the future using some method.

Forecast based on moving average: we accept the last balanced data as the value of the future period and calculate a moving average from it:

$$M_{t+1} = \frac{1}{k}\left(M_t + y_{t-1} + ... + y_{t-k+1}\right)$$

The M_t denotes the centred moving average that precedes the forecast data to be calculated.

Forecasting using mean absolute changes:

$$y_k^{'} = y_0 + k * \overline{D}$$

Results

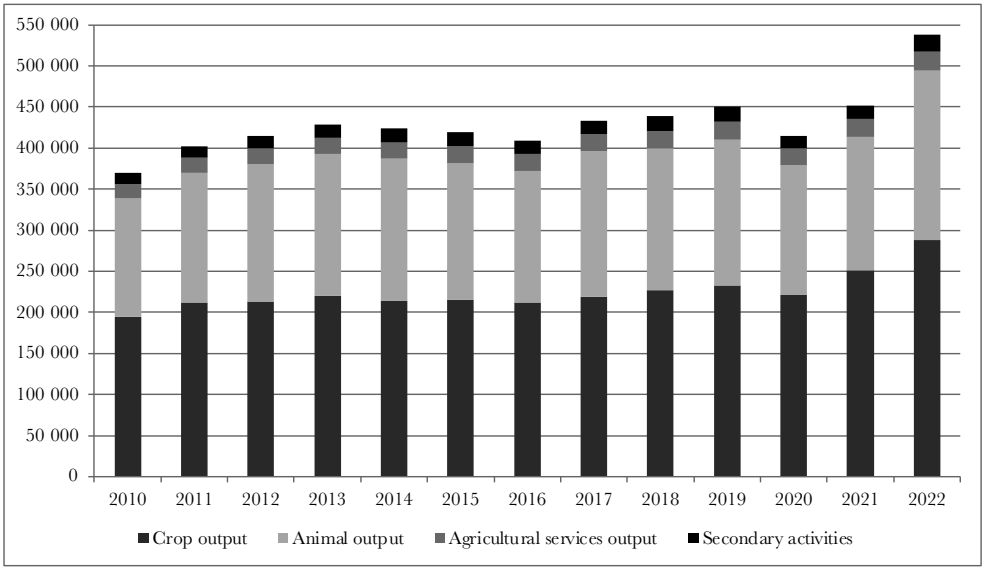
Development of Agricultural Production in the EU

In 2010, the agricultural production of the 27 countries of the European Union (Figure 1) was only €369,253 million, while in 2022, it was as high as €537,489.17 million. Compared to 2010, this represented an increase of 45.6%. In 2022, the value of agricultural production rose nominally sharply (+19%) compared to 2021. This was a new high. Slightly more than half of this emission (53.6%) came from crop out (€287.9 billion), within which cereals (€80.6 billion) and vegetables and horticultural products (€65.9 billion) were the most valuable crops. Nearly two-fifths (38.3%) of the total output came from animals and animal products (€206 billion), mostly from milk (€78.1 billion) and pigs (€42.1 billion). Agricultural services contributed 4.3% and secondary activities 3.8% to production (Eurostat, 2023b).

The contributions of the EU Member States to this production value showed significant differences. France (€97.1 billion), Germany (€76.2 billion), Italy (€71.5 billion) and Spain (€63 billion) together accounted for more than half (57.3 %) of the EU's total agricultural output value (Eurostat, 2023c).

In 2022, the EU agricultural sector generated an estimated gross added value of €220.7 billion. This is a contribution of 1.4% to the GDP of the EU-27, which means that the agricultural sector contributed €215.5 billion to the total GDP of the EU in 2022. In different terms, for every €1 spent on the costs of goods and services used in the production process, referred to as current production consumption, the EU agricultural sector created an added value of €0.70 (Eurostat, 2023c).

Figure 1: Output of the agricultural sector in EU-27, million €, 2010-2022.



Source: Author's editing based on Eurostat (2023c)

Energy Consumption in the EU

The gross available energy (from primary energy production and imports) in the European Union increased in 2021 (+6%) compared to 2020. However, despite the long-term downward trend, crude oil and petroleum products (34.5%) remained the most important energy sources in the European economy, while natural gas (23.7%) remained the second most important energy source. Both the amount of available oil (5.3%) and natural gas (4.0%) increased in 2021 compared to 2020. This is primarily due to the increase in activity after the COVID-19 pandemic. The share of renewable energy sources (17.4%) also continued to increase (Eurostat, 2023f).

Primary and Final Energy Consumption

The 1,457.6 million tonnes of oil equivalent primary energy consumption in 2010 (Figure 3) had decreased to 1,309 million tonnes of oil equivalent by 2021. The final energy consumption (Figure 3) was 1,025.5 million tonnes of oil equivalent in 2010, decreasing to 967.9 million tonnes of oil equivalent in EU-27 by 2021 (Eurostat, 2023d; Eurostat, 2023e). In both cases, we could therefore experience a decrease.

Based on my calculations, between 2010 and 2021, primary energy consumption decreased by an average of 13.51 million tonnes of oil equivalent (average absolute change) and final energy consumption by 5.15 million tonnes of oil equivalent (average absolute change). During the examined period, primary energy consumption decreased by 0.98% (average relative change) and final energy consumption by 0.52% (average relative change) annually.

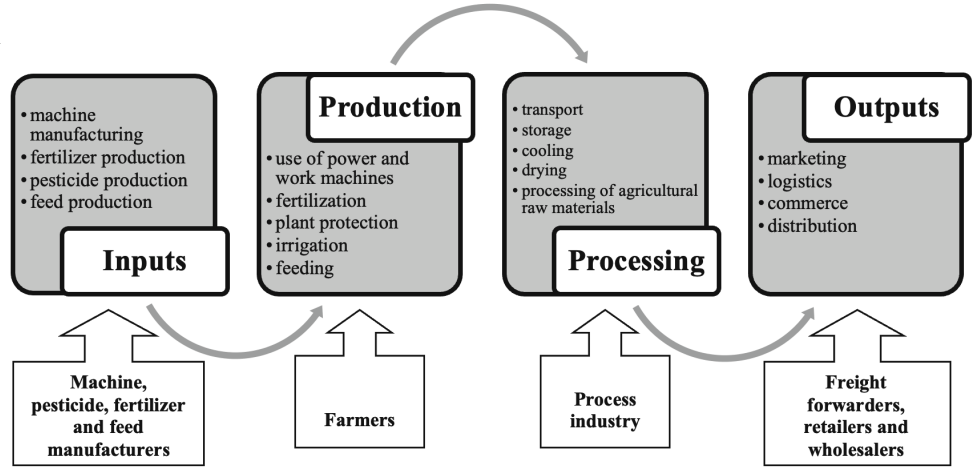
Compared to 2020, however, it can be seen that both primary (+6%) and final energy consumption (+7%) increased by 2021.

However, the amount and share of solid fossil fuels in final energy consumption decreased significantly, while the share of renewable energy sources increased. In the structure of final energy consumption in 2021, oil and petroleum products accounted for the largest share (34.8%), followed by electricity (22.8%) (Eurostat, 2023f).

Development of Agricultural Energy Consumption in the EU

If we examine agriculture and agricultural production, we will find that it is itself an energy transformation process. Through photosynthesis, solar energy is transformed into food energy for humans and feed energy for animals. Modern agriculture requires significant energy input at each stage of agricultural production (Figure 2). Energy is needed to operate agricultural machines, cultivate the soil, replenish nutrients, plant protection and care, irrigation and harvest. Post-harvest energy use includes energy required for food processing, food storage and transport to market. In addition, many indirect or fixed energy inputs are used in agriculture in the form of mineral fertilizers and chemical pesticides, insecticides and herbicides (FAO, 2000).

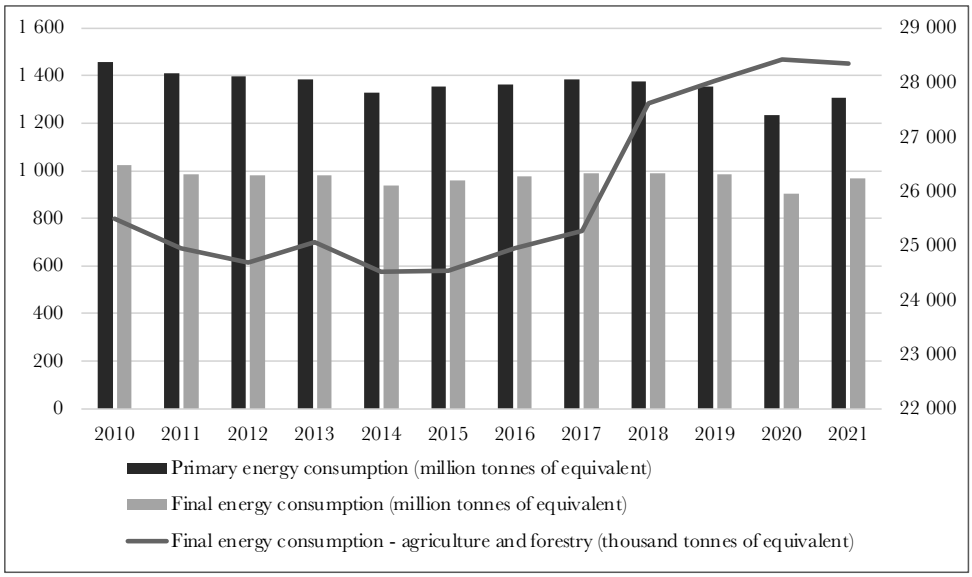
Figure 2: Development of Agricultural Energy Consumption in the EU



Source: Author's editing based on Energypedia (2014).

Agriculture and forestry accounted for 3% of the total direct final energy consumption of the EU (28,343,639 thousand tonnes of oil equivalent) in 2021 (Figure 3). At the member state level, the highest rate was in the Netherlands (9.2%) (Eurostat, 2023g; Eurostat, 2023h). There are more than 54,000 agricultural companies in the Netherlands. Despite its small area, the country emits more nitrous oxide and ammonia than any other EU country (Richardson, 2022).

Figure 3: Primary and final energy consumption (bar graph, left axis of values), final consumption - agriculture and forestry (line graph, right axis of value) in EU-27, 2010-2021.



Source: Author's editing based on Eurostat (2023d, 2023e, 2023h).

2018 was the most extreme year in terms of unusual weather phenomena on the continent. Heat and precipitation also set new records across Europe. Could 2018 be a turning point for the climate? Cereceda and Graham (2019) asked this very question. What makes 2018 particularly exceptional is that several weather events occurred at the same time over a very large area. We have not had that many weather events before. It is a combination of global warming and some unusual, very persistent weather patterns. We witnessed similar phenomena in the past few years, which presented agriculture with extraordinary challenges. Perhaps this also explains the 9.3% increase in energy consumption by the sector from 2017 to 2018.

From 2020 to 2021, the energy used by the agricultural sector decreased by 0.3%. This was in stark contrast to total energy consumption, which rebounded (+6.2%) from 2020 Covid-infected levels (EFA, 2023).

Based on Table 1, it can be seen that between 2010 and 2021, the final energy consumption in agriculture and the forestry sector increased by an average of 258.1 thousand tonnes of oil equivalent (average absolute change), i.e., by an average of 0.96% (average relative change).

Table 1: Result of time series analysis, final consumption – agriculture and forestry in EU-27, 2010-2025.

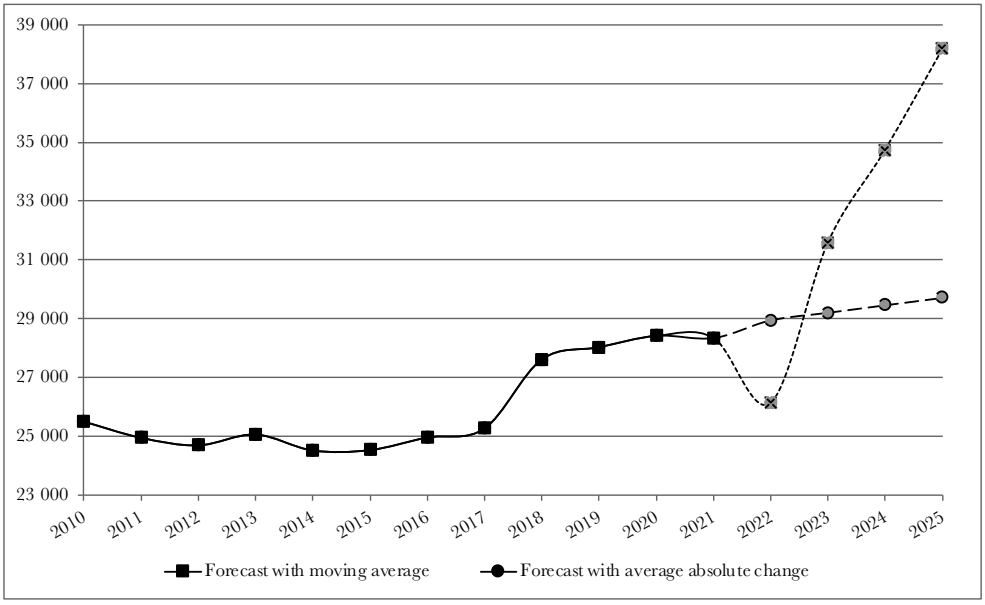
Fore- casting process Years	Final consumption of agriculture and forestry (1000 toe)	Change from the previous year (1000 toe)	Change in % of previous year	Average relative change (%)	Average absolute change (1000 toe)	10-member moving average (1000 toe)	Centring (1000 toe)	Forecast with moving average (1000 toe)	Forecast with average absolute change (1000 toe)
2010	25 504.503	0	0				0		
						0			
2011	24 952.740	-551.763	0.978366				0		
						0			
2012	24 692.197	-260.543	0.989559				0		
						25 049.813			
2013	25 061.924	369.727	1.014973				24 976.050		
						24 902.287			
2014	24 519.351	-542.573	0.978351				24 830.056		
						24 757.824			
2015	24 531.579	12.228	1.000499				24 731.054		
						24 704.285			
2016	24 960.147	428.568	1.017470	1.00964	258.103		24 687.322		
						24 670.359			
2017	25 266.405	306.258	1.012270				24 794.868		
						24 919.377			
2018	27 615.191	2348.786	1.092961				25 433.312		
						25 947.248			
2019	28 031.454	416.263	1.015074				26 459.132		
						26 971.017			
2020	28 418.149	386.695	1.013795				27 496.307		
						28 021.598			
2021	28 343.639	-74.510	0.997378				28 143.006		
						28 264.414			
2022								26 123.940	28 934.356
2023								31 570.698	29 192.459
2024								34 727.768	29 450.562
2025								38 200.545	29 708.665

Source: Author's calculation and editing based on Eurostat (2023h).

Since agricultural production in 2022 increased sharply (+19%) compared to 2021, it is likely that the sector's energy consumption also increased in 2022 and will continue to increase in the future. Weather anomalies have multiplied, the population is also constantly growing, so agriculture has to face more and more challenges and adapt to them with the achievements of modern technology. The sector must produce more and more to be able to safely supply the population with food, and this requires ever-increasing energy.

Figure 4 illustrates the expected development of agricultural energy consumption for the period between 2022 and 2025, determined by two types of forecasting methods.

Figure 4: Final consumption – agriculture and forestry in EU-27, 2010-2025 (thousand tonnes of oil equivalent)



Source: Author's editing based on Eurostat (2023h).

According to the FAO, agriculture is expected to produce 60% more by 2050 (compared to 2006-2007). This will manifest itself in business as usual, increasing overall energy demand and greater dependence on the fossil fuel market. Following recent trends, however, it can be expected that due to improvements in energy intensity, the total energy use of agriculture (i.e. fuels and primary production electricity) will increase less than the demand for agricultural products (Alexandratos and Bruinsma, 2012; Sims et al., 2015); therefore, the forecast data determined by the average absolute change should be accepted.

Discussion

Today's modern agriculture requires modern energy. Sustainable agriculture, the energy input of agricultural production and processing systems are key factors for self-sufficient farming and food security. In developing countries, agriculture is the dominant sector. Therefore, its role in developing the economy in these countries is decisive. The increase in productivity achieved by the modernization of agricultural production systems is the primary driving force for reducing global poverty, in which energy plays a key role (Energypedia, 2020).

Upon examining the agricultural production of the European Union between 2010 and 2022, we can conclude that it increased, with a new peak of 19% from 2021 to 2022.

If we look at the average absolute and relative changes in the Union's energy consumption, we can conclude that both primary (with 13.5 million tonnes of oil equivalent, 0.98%) and final energy consumption (with 5.15 million tonnes of oil equivalent, 0.52%) with) both decreased.

On the other hand, the energy consumption of the agricultural sector has increased (by 258.1 thousand tonnes oil equivalent, 0.96%), and will continue to increase based on the calculated forecasts. Thus, together with the increase in agricultural production, but not to the same extent, the sector's energy consumption has increased, even though the EU's energy consumption has decreased.

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