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Examination of first generation biofuel production in some selected biofuel producing countries in Europe: A case study

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Abstract: The EU is committed to increasing the use of renewable energy sources. In the sector of transportation, the share of renewable energy is to reach 10% by 2020 and 14% by 2030, respectively, in the EU. According to the latest forecasts, the production of the first-generation biofuels made from food raw materials is showing a declining tendency in the main European producing countries. Therefore, the objective of our research is to forecast the production of some selected biofuel producing countries within the EU as well as the traditional biofuel production in Hungary. The question of land use changes due to the new regulations is crucial. Our examinations were carried out by using Verhulst's logistic function based on the biofuel production data of EUROSTAT. The function has already reached the saturation level in Germany, France and Sweden but in the case of other examined countries, biofuel production is also in the phase of slowing growth. Furthermore, findings are also justified by the 2015 regulation that restricts the share of producing first-generation biofuels in the final energy consumption to 7% and promotes the production of advanced biofuels, thereby decreasing the indirect change in land use and increasing sustainable crop production.

Keywords: forecast; land use; logistic function; primary biomass

In Europe, the amount of biofuel consumed is mainly influenced by the Renewable Energy Directive I. (RED I.) of the European Union. This directive sets the share of renewable energy sources at 20% of total energy consumption, of which 10% is targeted for transportation. This target for transportation is mandatory in each member state, while the 20% obligation is the average value of the total renewable energy share (EC 2009). The directive also sets out the minimum biofuel share to be reached by the single states. However, member countries can individually decide on the extent of supporting biofuels and the opportunity of applying certain fuel standards.

The EU's biofuel policy was primarily aimed to decrease the level of dependency on fossil fuels and thus to improve the safety of energy supply as well as to reduce the emission of greenhouse gases (GHG), thereby slowing down climate change. Furthermore, demand was also generated to run off agricultural surpluses that were meant to solve the problem of subsidising farmers (Khanna et al. 2011).

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After adopting the Renewable Energy Directive II. (RED II.), the attention of the European Commission was focused on the land use changes caused by biofuels. In the transport sector in 2015 the share of biofuels made from basic agricultural products was limited to 7% while maintaining the 10% target (EC 2015). The remaining 3% has to be reached by waste and by-products in the case of which the directive allows double counting.

The European Commission plans to further increase the share of renewable energy in the energy mix by 2030. According to the RED II. Directive, the share of renewable energy sources in the EU's energy supply should be raised to 32% by 2030, while the transport sector should cover 14% of its energy supply from renewable energy sources (EC 2018). Due to sustainability concerns, the proportion of biofuels made from food raw materials will continue to be restricted at 7% (Popp et al. 2018). From 2021, the use of biofuels and bioliquids (palm oil) produced from high-risk raw materials for land use change will not count in meeting the Union's targets. The share of advanced fuels in gross final energy consumption should be raised to 0.2% by 2022 and 3.5% by 2030, respectively, which is not considered significant compared to the 10% proposed in the draft directive (EC 2018).

The European Union would be technically capable of producing the biofuels that are required to meet the 10% target by 2020, but this would not be economical and would also conflict with international trade policy (Yuzhakova et al. 2012). For this reason, most member states cover their needs partly from the imports of biofuels and partly from the processing of imported and self-produced raw materials. Imports are also needed so that the increase in biofuel production should not result in a significant increase in the price of agricultural products (ECOFYS 2013).

In international markets, the significant increase in the price of agricultural products is considered by several studies (Collins 2008; Mitchell 2008; Xiaodong and Lihong 2012) as the consequence of biofuel production, while other sources (Baffes and Haniotis 2010; Malins 2017), (Hochman and Zilberman 2016) state that biofuels may contribute to food price increase only to a small extent or no extent at all, rather, other economic phenomena such as unfavourable weather, population and consumer income growth, as well as changes in the price of crude oil, can influence the price of agricultural products.

The available databases were not always available for the same study duration at the time of manuscript preparation. We tried to examine the data for as long as possible, which started with Hungary's accession to the European Union and ended with the last available data in each study.

The ECOFYS (2013) study estimated the impact of biofuels produced in the European Union on the price increase of food raw materials. The EU's demand for biofuels has increased world cereal prices by 1–2% between 2000 and 2010 and is expected to increase by another 1% by 2020, without restricting the use of food raw materials for biofuels. Oilseed prices in the EU increased by about 4% over the same period due to biodiesel production and are expected to increase further by 10% without restriction.

Biofuel production within the EU has developed to a great extent nowadays (Figure 1). According to the EUROSTAT database in 2004 global biofuel production reached 2.677 ktoe. By 2018 this quantity tenfold accounting for 22.741 ktoe. Production was constantly growing till 2010, then in 2011 it decreased by 11% points compared to the previous year. Afterwards, production growth significantly slowed down. In 2016, about 80% of biofuels produced in the EU28 were biodiesel, with bioethanol production accounting for only 20% (BP 2019a,b). The primary end-user of biofuels is the transport sector (95%) (Bioenergy Europe 2019).

Sixty percent of cereals produced in the European Union are used for animal feed, which will not decrease significantly in the future, either (Figure 2). Food and industrial cereal use were still 39.8% in 2005, which is expected to decrease by 10% by 2026. Energy consumption will increase significantly as food use declines. Barely

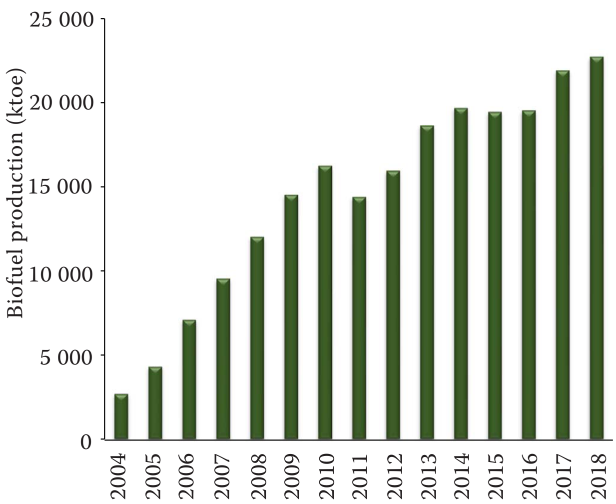

Figure 1. Changes in the biofuel production of EU28, 2004–2018

Ktoe – kilotonne of oil equivalent

Source: EUROSTAT (2020)

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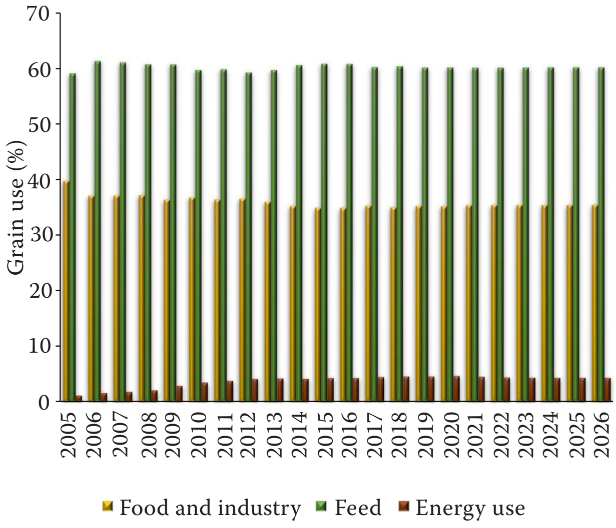

Figure 2. Breakdown of EU grain use

Source: EC (2016)

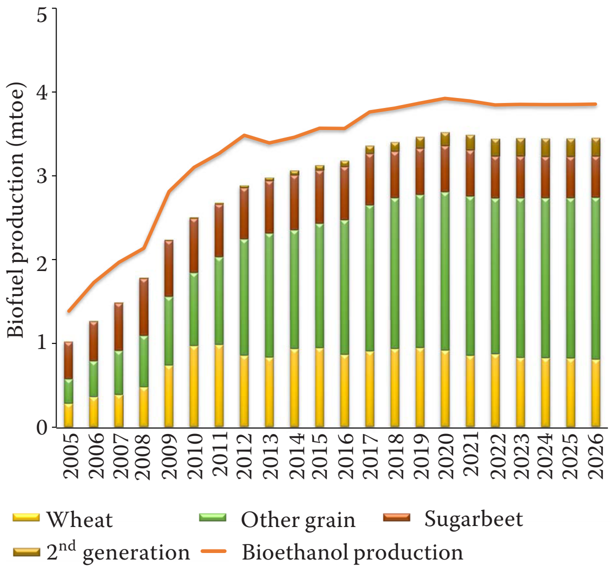

Figure 3. Changes in the EU's bioethanol production between 2005 and 2026 by raw materials

Mtoe – million tonnes of oil equivalent

Source: EC (2016)

more than 1% of the cereal crop was used for energy purposes in 2005, by 2015 it was already 4.2% and is expected to increase to 4.6% by 2020, then it will start declining slightly.

Cereal self-sufficiency is the highest in France, with barley and maize production exceeding 200%. Hungary has a similarly high index for maize and wheat. Spain's self-sufficiency rate is only around 70%, despite being Europe's largest producer and user of bioethanol in 2005, with production based on imported raw materials. However, in some member states, cereal production is far from meeting needs, e.g. Belgium, the Netherlands and Portugal have very low self-sufficiency rates.

In the European Union sugarbeet, wheat and other cereals were used in bioethanol production in almost equal proportions until 2008 (Figure 3). However, from 2012 onwards, the use of other grain (i.e. maize) has dominated production, while the use of wheat and sugarbeet has not changed despite the increasing amount of ethanol. In 2014, 40% of the bioethanol produced was from maize, 26% from wheat and 20% from sugarbeet, respectively. According to the EU's forecast for 2026, further increased use of maize in bioethanol production is expected (EC 2016). Second generation bioethanol production amounted to 2.9% in 2014 and no significant increase is expected in the EU due to high production costs.

EU bioethanol plants operated at a capacity of 85% in 2017. The feedstock dependent on the plant produced 4.64 million tonnes of bioethanol, and 5.71 million tonnes of co-products. Of the by-products, 4.32 million tonnes may be used as livestock feed (ePure 2017). By selling co-products, bioethanol plants can reduce the effect of biofuel output on land use and the environmental burden, as well as improve the profitability (Taheripour et al. 2010).

Biodiesel production in the EU is largely based on vegetable oils, but the use of waste (used cooking oil, waste fat) is also increasingly important (Figure 4). In 2015, 55% of the biodiesel in the European Union was produced from rapeseed oil, 18% from imported palm oil and 6% from soybean oil, respectively. Waste recovery represented 19% and only 2% of biodiesel production came from second generation biofuels. In the future, the use of waste in biodiesel production will be also high, but the growth of second-generation biodiesel, like the second-generation bioethanol, is not expected in the EU for 2026 (EC 2016).

According to the USDA forecast for 2019, growth in biofuel production in the EU will continue over the next decade, but at a slower rate in the major producing countries. As a result, the demand for biofuel raw materials will also grow more slowly (USDA 2019). The development of second-generation biofuels in the EU may only be anticipated to a slight extent in the future, owing to the high cost of output. If the new generation of fuel production is to substitute the first generation one, it will also have to be economically counterproductive. Although cereals, oilseeds and sugar demand and prices will grow less, demand

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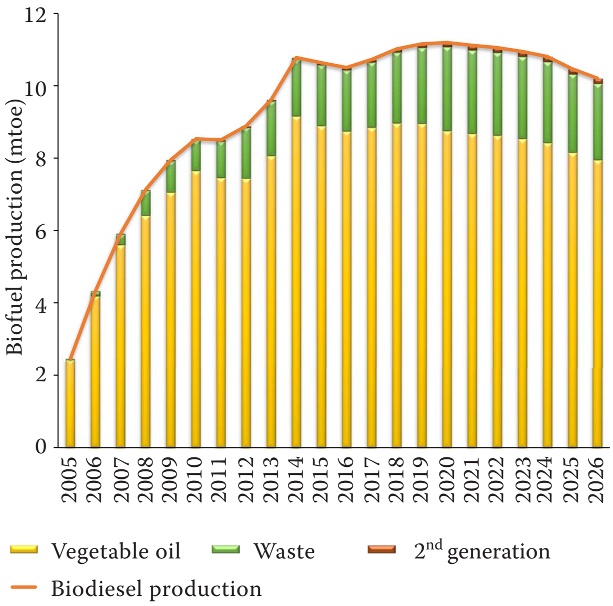

Figure 4. Changes in the EU's biodiesel production between 2005 and 2026 by raw materials (mtoe)

Mtoe – million tonnes of oil equivalent
Source: EC (2016)

and prices of wood products and crop by-products will increase. Reducing the production of first-generation biofuels would result in less affordable feed for animals, which would have a detrimental effect on livestock development by higher feed prices. Also, the crop structure of the field would be significantly transformed in favour of energy plantations (Guyomard et al. 2011).

The future of biofuel production primarily depends on the pace of technical progress and the findings of biofuel studies regarding the environmental and social effect. According to some projections, the bulk of energy demand for road transport in the future would not be fulfilled by fossil or biomass-based fuels but by hydrogen cells and electric batteries. While they do not provide useful by-products such as biofuels, energy for vehicle charging would be partly provided by hydro, solar, wind and tidal power plants and would have less effect on land use transition (Németh et al. 2020).

MATERIAL AND METHODS

The analysis is based on EUROSTAT (2020) biofuel production data for the period 2004–2015. Within the EU, Germany, Spain, France, Italy, the Netherlands and Sweden were the first countries to produce first-generation biofuels during the period under review, so the production figures of these countries were compared with the Hungarian production figures (Table 1). Time series analysis is based on the modified formula of the Verhulst logistic function with Δt. (Verhulst 1938; Cramer 2002).

Steady growth is not an assumption in the long run. A common feature of these processes is that they grow at a constant rate for a period of time, and after a while they reach the stage where growth constraints are already having an effect, resulting in a noticeably lower growth rate of 0 (Gut 2009).

The content of the logistic function is as follows (Equation 1):

$$y_t = \frac{k}{1+\exp\left[\beta_0 + \beta_1\left(t_i - \Delta t\right)\right]} \tag{1}$$

where: y_t – dependent variant in general; k – saturation parameter (saturation level); β_0 – shift parameter, if all is unchanged, its growth will shift the function to the right; β_1 – shape parameter, its growth (in absolute value) makes the function steeper; t – time change.

The inflexion point of the function indicates the significant changes in the evolution of the phenomenon and its expected time. After the inflexion point, the nature of development changes and slows down, so it can be considered a critical point of the function (Gut 2009).

The objective of our research is to forecast the production of some selected biofuel producing countries within the EU as well as the traditional biofuel production in Hungary. There was no direct aim to discover the question of land use changes due to the new regulations in this study.

Table 1. The rank order of countries in Europe with the most biofuel production

Ranking	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1.	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE
2.	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR
3.	IT	ES	SE	SE	IT	ES	ES	ES	NL	NL	NL	NL	ES	ES	ES

DE – Germany; ES – Spain; FR – France; IT – Italy; NL – the Netherlands; SE – Sweden
Source: EUROSTAT (2020)

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RESULTS AND DISCUSSION

In the European Union, the conditions for arable crop production vary. In countries with smaller areas, biofuels are produced with food security in mind. These countries try to fulfil their commitments by using either imported raw materials or imported biofuels. According to the EUROSTAT (2019), more than half (80% at the beginning of the period studied) of European biofuel production is realised by the countries in (Table 1) between 2004 and 2018.

Germany and France were the major biofuel producers. The rank order of the biofuel producing countries from the third place is more mixed. In the first half of the examined period Italy and Sweden were placed third in production for two-two years while in the second half of the period Spain and the Netherlands were the third in producing the most biofuel. In our research we have analysed how the production of conventional biofuels is expected to develop in the selected countries as well as in Hungary as one of the biggest bioethanol producers in Eastern Europe in the forthcoming years.

The 2009 RED I directive sets mandatory targets for the use of biofuels and not for their production. Each country has set a percentage target for the use of biofuels in the transport sector by 2020 in its renewable energy action plans (NREAP 2020). According to the progress reports, the growth in the use of biofuels in individual countries is slow. The 2017 Progress Report (EC 2017) states that the transport sector alone has not met its roadmap for renewable energy use at EU level. The 2015 performance, including multiple setoffs, was only 6% compared to the targeted 6.8%. This can be due to a number of difficulties identified in the European Commission's 2017 Progress Report, such as the high GHG mitigation costs and regulatory uncertainties such as the impact of indirect land use change and the use of food raw materials for energy purposes.

The percentage of the renewable energy used in the transport sector of the examined countries together with the projected amounts in the action plans form 2004–2015 and the prediction for 2020 is presented in (Table 2). Germany, Spain, Italy and the Netherlands were unable to meet their pro rata requirements. The greatest lag was observed in Spain as it was able to meet only 18.28% of its 2018 commitments. In 2015 Hungary exceeded its commitment of renewable energy use in transportation by more than 14% while Sweden already met its 2020 transport liabilities in 2011.

Some countries produced much more biofuel in certain years than they used. The surplus was sold to other countries. (Table 3) shows the balance between production and use.

In Germany, Spain, Hungary and the Netherlands, the production of excess biofuels is observed. From 2013 the Netherlands produced a significant amount of surplus, while Italy covered its use from imports instead of its own production, so that the arable crops produced were not used for energy purposes. In Sweden, according to the EUROSTAT (2019) data, by 2012, exactly as much biofuel was used as produced, and from 2013 onwards, imported energy was also used to meet the high energy consumption. Despite Spain falling far short of its energy strategy commitment, from 2014 it did not use the biofuels it produced but sold it to other countries. In countries with higher biofuel production than utilisation, the environmental burden is also likely to be higher, as the biofuel produced is not used in one country but in another, and thus GHG savings occur elsewhere.

Up to and including 2016, the auto logistic curve fitted to the time series giving a close fit. Our expectation was that the estimate for the following years

Table 2. The amount of energy used in the transport sector and the 2020 targets in the examined countries (%)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Target	
													2015	2020
DE	2.2	4.0	6.8	7.5	6.4	5.9	6.4	6.5	7.5	6.9	7.2	6.6	7.0	13.2
ES	1.0	1.3	0.8	1.4	2.2	3.7	5.0	0.6	0.7	0.8	0.8	1.2	9.3	13.6
FR	1.5	2.1	2.3	4.0	6.2	6.6	6.5	1.0	7.6	7.7	8.4	8.5	7.7	10.5
HU	0.9	0.9	1.1	1.5	5.1	5.7	6.0	6.0	5.9	6.2	6.9	7.0	5.4	10.0
IT	1.2	1.0	1.0	1.0	2.6	3.9	4.8	5.0	6.0	5.4	5.0	6.4	6.6	10.1
NL	0.5	0.4	0.8	3.1	2.9	4.5	3.3	4.8	4.9	5.1	6.2	5.3	6.0	10.3
SE	6.3	6.2	7.1	8.0	8.3	8.9	9.2	11.6	14.8	19.2	21.1	24.0	10.7	13.8

DE – Germany; ES – Spain; FR – France; HU – Hungary; IT – Italy; NL – the Netherlands; SE – Sweden
Source: EC (2017); EUROSTAT (2019)

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Table 3. Balance between biofuel production and use (ktoe)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
DE	–46	–359	–541	–400	–266	–201	141	155	–166	282	612	532	207	302	272
ES	0	0	0	–4	–237	–186	–413	–878	–1 490	–31	349	255	301	578	163
FR	61	54	–35	–304	–235	–139	–154	–362	–292	–230	–342	–397	–487	–584	–292
HU	0	0	0	–12	–3	–15	–32	–17	140	146	130	204	422	460	436
IT	0	0	0	0	–113	–624	–1 148	–1 292	–1 600	–1 430	–1 297	–1 426	–1 343	–1 182	–1 271
NL	–77	–271	–306	–338	–389	–142	171	125	634	1 103	1 187	1 126	1 129	1 256	881
SE	0	0	0	0	0	0	0	0	0	–313	–609	–818	–1 099	–1 441	–1 395

DE – Germany; ES – Spain; FR – France; HU – Hungary; IT – Italy; NL – the Netherlands; SE – Sweden
Source: EUROSTAT (2020)

would deviate from the actual figure by less than 10%. However, the deviation significantly exceeded this value, and actual production became large by 2018. Examination of the reason for this discrepancy is beyond the scope of the present study.

The accuracy of the function fitting was checked by means of a correlation coefficient, the value of which shows a strong correlation between the biofuel production and the trend in each of the examined countries (Table 4).

By replacement of the parameters into the logistic function it could be explored that in case of Germany, France and Sweden the production is close to its predicted maximum (see relative change of the predicted biofuel production from 2014 to 2015). In the other analysed countries the growth of the biofuel production decreases.

The results are also supported by the U.S. Department of Agriculture (USDA 2017) report that first-generation biofuel production in Germany, France and Sweden is not expected to increase in the future. According to the trend calculations based on production data, biofuel production in Spain is expected to decline. Spain plans to expand its biodiesel production capacity by approximately 20%. No increase in production is expected in Italy and the Netherlands. In Hungary, usable raw materials are abundantly available for the production of first-generation biofuels. However, due to EU regulations, no significant increase in production is expected in the future. (Bai et al. 2016) is also of the same opinion about the future development of biofuel production in Hungary. According to the USDA report (USDA 2017), bioethanol production in the country will increase by only about 1% in the future.

CONCLUSION

The production of biofuels is essentially a political decision. The arguments in favour of biofuel production include environmental, energy and agricultural concerns. Different factors encourage countries to increase the production and use of biofuels. Due to a mixture of many factors, national strategies are not entirely

Table 4. Parametres of the logistic function in the examined countries

Country	Parameters (time series 2004 to 2016)					Relative change (2014–2015; %)	Testing forecast (2017–2018)			
	biofuel production (k max; ktoe)	β_0	β_1	Δt (year)	r^2 (2004–2016)		r^2 (2004–2018)	relative difference from trend value (%)		
								2016	2017	2018
DE	3 400	–1.5	1.0587	5.0	0.9460	0.00	0.8410	–0.8	17.5	19.8
ES	1 200	–0.6	1.0202	2.0	0.8956	0.68	0.8114	15.1	75.2	78.1
FR	2 500	–0.9	1.0618	3.5	0.9737	0.03	0.9102	–3.7	29.2	44.3
HU	400	–0.6	1.0100	0.0	0.9537	2.21	0.8995	5.5	51.8	60.6
IT	900	–0.6	1.0202	2.0	0.7240	0.68	0.7610	12.2	8.0	18.6
NL	1 500	–1.2	2.7183	0.0	0.9744	0.47	0.9575	–13.7	28.7	26.7
SE	350	–0.6	1.0513	5.0	0.7323	0.12	0.6957	–19.7	–11.1	46.9

DE – Germany; ES – Spain; FR – France; HU – Hungary; IT – Italy; NL – the Netherlands; SE – Sweden; for abbreviations see Equation (1)
Source: Own calculation based on EUROSTAT (2018)

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clear, as they simultaneously demand the promotion of imports, environmental objectives and the protection of domestic producers. The contradiction is understandable since environmental and energy goals can be achieved most economically by imported biofuels, because developing countries produce them much cheaper and, in this case, emissions from production also occur elsewhere. However, the use of imported biofuels is in contrast with the interests of agriculture.

In our study, we examined the expected changes in biofuel production by using logistic trend calculations. According to the results, in Germany, France and Sweden, the function has already reached saturation level, but in the other examined countries biofuel production is in a phase of slowing growth. This result is further justified by the European Commission's restrictive regulation of 2015, which limited the share of first-generation biofuels in final energy consumption to 7% and promotes the production of advanced biofuels, thereby reducing indirect land use change and increasing sustainable arable crop production. Nevertheless, by 2020, 10% of final energy consumption in the transport sector in the European Union should come from renewable sources. In addition to biofuel use, 10% also includes biogas use, renewable electricity and hybrid propulsion. According to EUROSTAT (2019), the EU28 average share of renewable energy in transport in 2016 was 7.1%. The use of first-generation biofuels varies according to their potential. According to our results, the production of first-generation biofuels will not increase significantly in the EU member states. Further increases can only be caused by a rise in fuel use and an increase in biofuel blending ratio.

The possibility of producing conventional biofuels, as expected in the literature, did not encourage farmers to significantly increase the efficiency of arable crop production although the crop structure has shifted towards higher production of oilseeds. To meet the 2020 targets, the use of renewable electricity and advanced biofuels in the transport sector needs to be increased. Due to the high production costs, a higher rate of production of second-generation biofuels is not expected in the future. In Europe, the production of advanced biofuels from used cooking oil and animal fats is still more common while the production of biofuels from cellulose is less observable. While the number of electric and hydrogen-powered cars is increasingly growing, the infrastructure is still not ready for smooth service. In the future, electric propulsion will be more economical than biofuels by upgrading technologies. Thus, at the moment, most of the alternative fuels we can use biofuels are there to combat climate change. Restrictions due to the Covid-19 epidemic have also negatively affected the biofuels market. Further studies are needed to analyse the economic impact of the epidemic.

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