ENVIRONMENTAL EFFICIENCY IN THE CONTEXT OF ACHIEVING EU CLIMATE TARGETS

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Abstract: The European Union is actively involved in the fight against climate change by setting national and international goals in the field of environmental protection. An important and globally monitored indicator is Net greenhouse gas emissions (GHG), the reduction of which was enshrined in the Europe 2020 Strategy and is subsequently the subject of the 2030 Agenda. The contribution focuses on the evaluation of the fulfillment of the main climate goal set in the Strategy 2020 and on the analysis of the environmental efficiency of member countries in reducing Net greenhouse gas emissions (GHG). The method of distance from a fictitious object was used to evaluate the set climate target, and environmental efficiency was measured in the period 2010-2020 using the DEA method. The chosen methods made it possible to reach the conclusion that up to five countries, such as Ireland, Luxembourg, Cyprus, Spain and Austria, failed to meet the set climate goal by 2020. By means of the DEA method, significant differences in environmental efficiency were detected between countries that joined the EU before and after 2004. Lower environmental efficiency was achieved to a greater extent by countries that joined the EU last. The presented study assumed that countries that did not reach the set goal have low environmental efficiency. However, this turned out to be a false assumption and countries like Ireland and Luxembourg were included among the states with the highest environmental efficiency. The results may indicate that the climate goals at the national level were set too ambitiously in these countries.

Key words: environmental efficiency, environmental behavior, green management, DEA, GHG, Strategy Europe 2020

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Introduction

Environmental protection and sustainable development are the basic priorities of the European Union, which has enshrined them in key documents at the transnational level. Member states are also aware of the need for measures aimed at climate protection, and in many cases they set their national goals even beyond the EU goals. Despite its primarily economic origins, the EU has become one of the main international actors in environmental protection (Mathis, 2020).

One of the important EU initiatives after 2000, which included climate protection among its priorities, was the Europe 2020 Strategy adopted in 2010 (European Commission, 2010). Key components of the climate and energy goals were renewable energy sources, reduction of greenhouse gas emissions and energy efficiency, which fell under the pillar of sustainable growth (Štreimikienė et al. 2016). On-going analyzes of the fulfillment of goals in the context of the sustainable growth pillar have shown significant progress of countries towards meeting the given criteria. The difference in the individual capabilities of countries was also demonstrated (Naterer et al., 2018; Liobikienė and Butkus, 2017; Moreno and Garc'ıa-Alvarez, 2018, Simionescu et al. 2022). The priority goal of mitigating climate change is to reduce greenhouse gas emissions climate-damaging gases (Net greenhouse gas emissions (GHG)), which come from human activity, through measures such as the promotion of low-carbon technologies and practices or the promotion of sustainable forest management and land use that increase carbon removal (European Union, 2023). The first objective of the Europe 2020 strategy in the area of climate change and energy was to reduce greenhouse gas emissions by 20% compared to 1990 levels, which was also reflected in the 2030 Agenda as Sustainable Development Goal (SDG) 13: Climate Change. set an even more ambitious target of reducing GhG at EU level by at least 55% compared to 1990.

In 2019, the EU announced its “Green Deal”, aiming for a carbon-neutral society by 2050 (European Commission, 2019). Despite the fact that the agreement prioritizes the environmental dimension of sustainable development, its goal is also a "just and inclusive transition" and the creation of jobs by supporting industry and the green economy. Both the Green Deal and the Sustainable Development Goals therefore overlap considerably with the previous Europe 2020 strategy.

The main cause of the problem is the increase in greenhouse gas emissions such as CO_2, CH_4, NO_2, etc. is the worldwide dependence on fossil fuel energy, industrialization and the use of fossil fuel cars, or transport in general (Peng et al. 2017; Liu et al. 2018a; Zha et al. 2020, Siddique et al., 2021). Another important cause is unsustainable economic growth (Neves et al. 2020), while one of the options for solving the problems of environmental efficiency is an orientation towards the circular economy (De Pascale et al. 2020; Mhatre et al. 2021). Some change in the decline of greenhouse gases has been seen under the influence of the Covid 19 pandemic, which has had an unprecedented impact on global energy consumption due to government-enforced lockdowns and a virtual shutdown of major economic activities (Smith et al., 2021; Gavurova et al. 2022). A study by Liu et al. (2020a)

showed a global decrease of 7.8% in CO_2 emissions due to reduced fossil fuel consumption during the first quarter of 2020 compared to the first quarter of 2019, but this was only a short-term improvement, which is also confirmed by the study of Kumar et al. (2022).

The reduction of greenhouse gases as well as the setting of other environmental goals was and still is conditioned by the adoption of a whole series of laws, regulations as well as decisions at the level of fiscal policy, which are supposed to ensure the growth of the environmental efficiency of EU countries (Duľová Spišáková et al., 2020). Environmental efficiency represents the ability of member states to produce goods and services while minimizing the negative impact on the environment. Demand for environmentally efficient products and services is increasing in countries, as governments increasingly focus on sustainable development and reduction of negative environmental impact (Beltrán-Esteve and Picazo-Tadeo, 2017; Dat andHung, 2023; Dat andLe, 2023, Veselovska, 2023).

The presented study is devoted to the evaluation of the success of the environmental goals in the field of GHG reduction valid until 2020 and subsequently to the measurement of the environmental efficiency of the member countries in the period 2010-2020. The aim of the study is to demonstrate the existence of significant differences in the environmental sustainability of the member countries, and whether weak environmental efficiency has a relationship with success in achieving the set goals of reducing greenhouse gas emissions.

Literature Review

The set goals in the area of reducing greenhouse gas emissions were supported by specific measures in the area of the economy and the environment sector. Measures such as "the polluter pays", support for the transition to a circular economy, subsidy schemes aimed at reducing negative externalities, the introduction and increase of environmental taxes and others were introduced. Other set goals of the Europe 2020 strategy, such as energy sustainability and the transition to renewable energy sources, also had an impact on the decrease in greenhouse gas emissions. Many of these measurable variables formed inputs for the assessment of environmental efficiency in the context of reducing greenhouse gas emissions in EU member countries (Ahmad et al. 2022; Skare et al. 2024).

A large number of authors have analyzed how successful EU countries will be in achieving energy and climate policy goals in the context of the Europe 2020 strategy (Ruser and Anheier, 2014; Becker et al., 2020; Fedajev et al., 2020; Roth and Thum, 2020, Lucian, 2022; Wust and Rogge, 2022; Gyori, 2023). A selected group of authors addressed the specific goal of reducing greenhouse gas emissions. Picazo-Tadeo et al. (2014) predicted that emissions in 2020 (outside the EU ETS) in most EU member states will be below their national EU targets. Roelfsema et al. (2014) revealed that the policies planned at that time would not be sufficient to fulfill the conditional promise of reducing greenhouse gas emissions and it would be necessary to proceed to more radical environmental measures. Similar conclusions were also

drawn by studies such as Capros et al. (2014), Hôglund-Isaksson et al. (2014), Jagemann et al., (2013), Markandya et al. (2014). The results of regression analysis Liobikienė and Butkus (2017) showed that economic growth and increasing primary energy consumption will contribute to the growth of greenhouse gas emissions in the EU, which can negatively affect the achievement of goals. Guzowska and Kryk (2021) also pointed out the difficulties of some countries in achieving this goal. Gontkovičová and Duľová Spišákova (2023) evaluated the fulfillment of the goal in the area of reducing greenhouse gases for the entire period of implementation of the Europe 2020 strategy with the conclusion that not all countries managed to fulfill these goals in the end.

In recent years, many research papers on environmental efficiency have appeared, with long-term greenhouse gas emissions in the center of interest. Some studies focus on solving the problem at the micro level (Latruffe et al., 2013, Dirik et al., 2022; Park et al., 2018), but significantly more studies focus on the macroeconomic level of countries, regions and economies (Chen et al., 2019; Iram et al., 2020; Mardani et al., 2017). At the national level, these are studies focused on environmental efficiency, primarily in China and the USA (Li et al., 2021; Chen et al, 2019), at the transnational level, they are groupings of EU or OECD countries (Halkos and Petrou, 2019; Czyzewski et al. 2020; Hermoso-Orzáez et al., 2020; Puertas et al., 2022; Zhu et al., 2022).

When evaluating environmental efficiency, the authors identified a different level of environmental efficiency between the old and new member states. Some research results have concluded that old members have higher environmental efficiency (Beltrán-Esteve et al. 2019); Matsumoto et al., 2020; Sanz-Díaz et al., 2017, Zhu et al., 2022), while which there are also studies that claim that new members achieve a faster increase in environmental efficiency than old EU members (Duman and Kasman, 2018). Duman and Kasman (2018) confirmed that over time, member states are getting closer to each other and achieving stable growth. These results are consistent with those of Zhu et al. (2022) who argue that between 2013 and 2019 there was a stagnation in the environmental efficiency of member countries, which supports the above steady state findings. Zhu et al. (2022) applied the DEA method to investigate three different objectives of environmental policy in EU countries in the period 2013-2019. He confirmed that there are significant differences between states, where countries that joined the EU earlier have higher efficiency values. A study by Bovenberg (2023) also achieves the same results, pointing to a large difference between the efficiency scores of old EU members and those who joined from 2004 or later. Furthermore, environmental efficiency appears to be influenced by institutional quality and political orientation. Hermoso-Orzáez et al. (2020) using two selected variants of the DEA method on a sample of EU member countries in the period 2005-2012 also confirms that countries with very low environmental efficiency included the last acceding countries, where environmental policies are not yet effectively applied with positive results. Puertas et al. (2022) on the analysis of 20 European countries in the period 2014-2018 confirmed that countries with low

environmental efficiency are concentrated in the East of Europe. For this purpose, they used the DEA method and the Malmquist Index (MI). Czyzewski et al. (2020), who studied EU countries in 2005-2016, concluded that the highest efficiency of environmental spending in the context of "deadweight loss" was recorded in the countries of Central and Eastern Europe, in the Scandinavian countries and in Spain. The findings of Lacko and Hajduov (2018) show that countries with higher eco-efficiency scores can further increase them by implementing or by increasing environmental taxes. Environmental taxes present important indirect economic tool for achieving of environmental goals in the sense of environmental burden decreasing (Csikosova et al., 2021). Conversely, countries with lower efficiency scores may experience a decrease in efficiency after tax increases. To the authors' surprise, the effects of waste policy had the same effect as environmental taxes.
The environmental behavior of all subjects, both residents and companies, is a prerequisite for meeting climate goals and high environmental efficiency. It is important to promote green management in all decision-making processes, especially in areas that significantly contribute to the creation of emissions.

Research Methodology and Aim

The main goal of the presented study is to measure the environmental efficiency of EU countries in the context of achieving the climate goals of the Europe 2020 strategy. The essence of the research is the verification of the following two hypotheses, the determination of which is based on theoretical foundations:
H1: Exist significant differences in environmental efficiency between EU member countries.
H2: EU countries that have not met the climate goal have low environmental efficiency.
The subject of the study was 27 EU member countries in the period 2010-2020, which represents the period of implementation of the Europe 2020 strategy. Based on the available data in the Eurostat database, the success rate, or failure to reduce GHG by 20% compared to 1990 according to the approach applied by Gontkovičová and Dulova-Spisakova (2023). The method of distance from a fictitious object was used, on the basis of which it was possible to evaluate the percentage success or failure of achieving the goal set at the national level. The distance from a fictitious object method is one of the most accurate methods within the framework of multicriteria methods. It shows the distance of an object from the ideal object, which achieves the best values in all indicators (max./min. according to the character of the indicator). The essence of this method is to create a fictitious (optimal) object O_0, in which all destimulating indicators acquire the minimum value mini $\{x_{ij}\}$ and all indicators with a stimulating character the maximum value maxi $\{x_{ij}\}$ from the values occurring in the set of compared objects $\{O_i\}$.

For the stimulating variable:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}, (i = 1,2, \dots, m; j = 1,2, \dots, k). \quad (1)$$

For the destimulating variable:

$$z_{ij} = \frac{\bar{x}_j - x_{ij}}{s_j}, (i = 1,2, \dots, m; j = 1,2, \dots, k). \quad (2)$$

The coordinates of the fictitious object O_0 are then:
For the stimulating variable:

$$z_{0j} = max_i\{z_{ij}\}, (i = 1,2, \dots, m) \quad (3)$$

For the destimulating variable:

$$z_{0j} = min_i\{z_{ij}\}, (i = 1,2, \dots, m) \quad (4)$$

where $z_{ij}(i = 1,2, \dots, m)$ are the normalized values of the indicators.
The average distance for each object Oi (i = 1, 2… n) from this fictitious object O_0 is calculated:

$$d_i = \sqrt{\frac{1}{k}\sum_{j=1}^{k}(z_{ij} - z_{0j})^2} \text{ (Euclidean distance)} \quad (5)$$

The lowest value $d_{i0} = 0$ is achieved by the object with the best performance in the observed indicator. In the final ranking, the best object (first) is the one with the smallest distance from the fictitious object when calculating the ranking for multiple indicators (areas of education, climate change and energy sustainability). In the case when we calculate the distance from the fictitious object based on only one indicator (areas of employment, research and development and poverty), the best rated object - Member state will be identical to the fictitious object. The worst object with a rating of m will be the Member state with the greatest distance from the fictitious object (Duľová Spišáková et al., 2023).
To measure efficiency, the DEA method implemented in R studio was chosen, which is among the most commonly used methods for evaluating environmental efficiency (Wei et al., 2021; Tian et al. 2020). Its use in the given area can be confirmed by a number of studies, see for example Moutinho et al. (2017), Park et al., (2018), Wegener and Amin (2019), Matsumoto et al. (2020) or Zhu et al, 2022 etc.
Data envelopment analysis (DEA) is a mathematical programming approach that allows the performance of decision making units (DMUs) to be evaluated. In this evaluation, the inputs that were invested in the process are compared with its achieved results (outputs) (Charles et al. 2018, Huynh and Hoang 2023). In the area of environmental efficiency, the division of outputs into desirable and undesirable is added (Goto et al., 2014). In the context of environmental efficiency, DMUs can be countries, regions, organizations or firms, and inputs and outputs can be

environmental indicators such as greenhouse gas emissions, water consumption, energy consumption or waste generation. DEA has been widely accepted in the scientific community due to its great flexibility in defining the problem: it accepts different units of measurement for inputs and outputs and allows direct comparison of some DMUs with others as well as with their combination (Lotfi et al., 2020).
Based on the previous studies, the inputs and outputs were defined, which formed the basic data sample for the DEA analysis. To increase the prediction capabilities of the estimated model, it is necessary to minimize the total number of inputs and outputs (m + s). As the number of input and output characteristics increases, so does the number of limiting conditions necessary to express the efficiency limit. Therefore, it is recommended that the total number of inputs and outputs does not exceed 1/3 of the number of examined DMUs. We applied a model based on Seiford and Zhu (2002). Let DMU_j denotes *n* independent decision units ($j = 1,2,\ldots,n$), each DMU_j needs *m* inputs x_{ij}, ($i = 1,2,\ldots,m$) to produce s_1 desirable outputs $y^g_{\bar{r}j}$ ($\bar{r} = 1, 2, \ldots, s_1$) and s_1 undesirable outputs $\bar{y}^b_{\bar{\bar{r}}j}$, ($\bar{\bar{r}} = 1, 2, \ldots, s_2$). Model is given by the following expressions:

$$Max\ ß_p$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{ip}, \qquad i = 1,2 \ldots,m,;$$

$$\sum_{j=1}^{n} \lambda_j y^g_{\bar{r}j} \geq ß_p y^g_{\bar{r}p}, \qquad \bar{r} = 1,2, \ldots s_1,$$

$$\sum_{j=1}^{n} \lambda_j \bar{y}^b_{\bar{\bar{r}}j} \geq ß_p \bar{y}^b_{\bar{\bar{r}}p}, \qquad \bar{\bar{r}} = 1,2, \ldots s_1,$$

$$\sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0, \qquad j = 1,2 \ldots n$$

$$where\ \bar{y}^b_{\bar{\bar{r}}j} = -\bar{y}^b_{\bar{\bar{r}}j} + w_{\bar{\bar{r}}} > 0 \tag{6}$$

For the purposes of the contribution, the DEA analysis was constructed in the context of achieving the first climate goal of the Europe 2020 strategy, which was the reduction of greenhouse gases. For this reason, variables such as Sulfur oxides (SOx) (t/GDP), (CO_2) per inhabitant (t/GDP), Nitrogen oxides (NO_2) listed in t/GDP, which were selected based on the studies of Halkos and Petrou (2019), Yang et al. (2014), Zhu et al. (2022) and Halkos and Petrou (2019). Considering that the reduction of greenhouse gas emissions should not hinder economic growth, GDP per capita was determined as the desired output, which has its theoretical justification in studies such as Puertas et al. (2022), Apergis, Garcia (2019).
The input variables were also selected on the basis of already existing studies. Emphasis was placed on the selection of indicators that directly affect the reduction of GHG production. Specifically, it was total public sector spending (% GDP) and

public spending on environmental protection (% GDP), which were selected based on studies such as Czýewsky et al. (2020), Melledu and Pulina (2018). In connection with the demonstrable effect of the introduction and regulation of environmental taxes on the decrease of greenhouse gases, the variable income from environmental taxes (% of GDP) was added based on the study of Štreimikienė et al (2022). From the set of other climate goals in the Europe 2020 strategy, the indicator primary energy consumption (t/GDP) was added, which was based on the study by Jiandong et al., (2015), Mavi et al. (2019).

Research Results and Discussion

In order to reach comprehensive conclusions, it is necessary to divide the analytical part of the contribution into two parts. The first part focuses on evaluating the success or failure of achieving the GHG reduction goal using the distance method from a fictitious object. The second part is dedicated to the measurement of environmental efficiency, which refers to the ability to achieve set goals with the help of selected tools, or outputs without negative impacts on the economic growth of member countries.

For the successful continuation of the reduction of climate goals, it is necessary to evaluate the changes that occurred in the process of implementing the Europe 2020 strategy. Based on Eurostat data, the GHG value was calculated in 2010 and 2010 with the index 1990 = 100. The results are illustrated in Figure 1. Overall, a decrease in GHGs is visible in all member countries between 2010 and 2020. The lowest value in 2020 was reported by Estonia, where GHGs reached the level of 28.4% of the value in 1990. Among the countries with the lowest emissions in 2020 also Latvia, Lithuania, Romania, Bulgaria and Slovakia. On the contrary, Cyprus, Ireland, Portugal and Spain recorded a high value. On average, there was a reduction of GHG at the level of 19.07% among the EU countries. The biggest share of this decline between 2010 and 2020 was environmental behavior and measures in Greece (down 42.3%), Finland (down 38.1%), Denmark (down 31.7%) and Malta (down 30.2%). In terms of national improvement, the most significant decrease (change in the volume of GHG produced between 2010 and 2020) was recorded in Estonia by up to 46%, Denmark (decrease by 35%) and Malta by 33.6%. Latvia achieved the least improvement in GHG volume (down by 3%), but this country has long had one of the lowest greenhouse gas emissions in Europe. High values are achieved, for example, by Ireland, which managed to reduce GHG by only 8%. From the point of view of the division of countries into old and new member states, most of the countries that joined the EU after 2004 are below the average of the EU countries, with the exception of Poland and Croatia, whose achieved values are among the countries achieving above-average GHG.

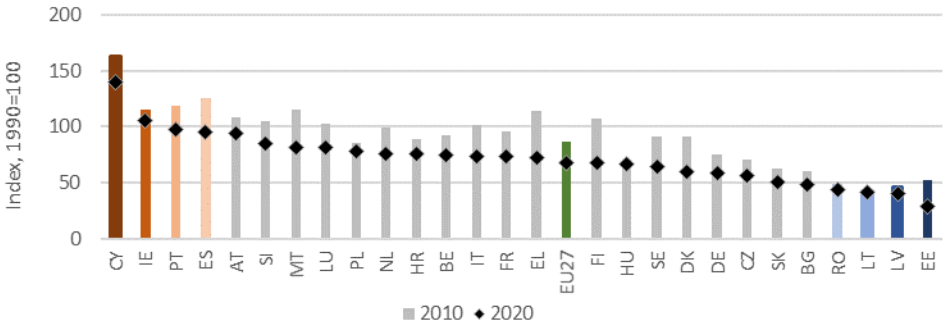

Figure 1: Net greenhouse gas (GHG) emissions, 2010 and 2020 comparison
Source: Own elaboration according to Eurostat data

The fulfillment of national goals was examined based on the method of distance from a fictitious object, which monitored the size of the distance of the achieved goal in 2020 from individually set goals in achieving the reduction of greenhouse gas emissions. Based on Eurostat data and the results of the analysis presented in the publication Duľová Spišáková et al. (2023) the data was recalculated with the evaluation in Figure 2.

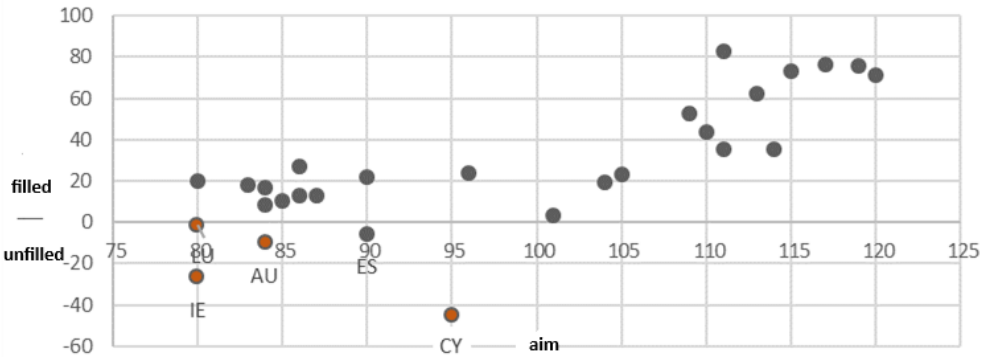

Figure 2: Distance of countries from the target values for the indicator of net greenhouse gas emissions in 2020
Source: Own elaboration based on data from Eurostat, 2023 and Duľová Spišáková et al. (2023)

With the exception of five countries, Member States have achieved the target of reducing net greenhouse gas emissions. Luxembourg was the least behind the target value by 1.4%, Spain by 5.3%, Austria by 9.8%, Ireland by 26.2% and Cyprus most significantly by 44.7%. Among the group of countries that did not meet the given climate goal, there is not a single country that joined the EU after 2004, so these are old member states. New member states such as Estonia, Croatia, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovenia and Slovakia had the opportunity to increase emissions compared to 1990, which is specific to this target.

Their starting situation in 2010 was very good compared to the old member countries, as illustrated in Figure 1.

Using defined desired and unwanted outputs as well as inputs, environmental efficiency was calculated for each EU country in the years 2010-2020. Figure 3 presents the efficiency results for the years 2010 and 2020 and shows the change in efficiency development at the beginning and at the end of the Europe 2020 strategy.

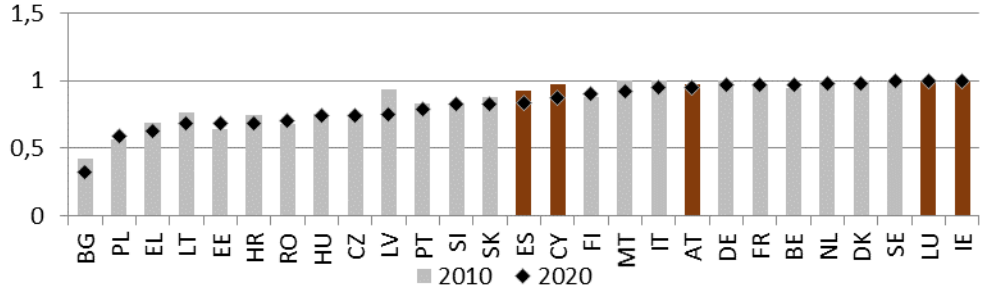

Figure 3: Environmental efficiency of EU member countries
Source: Own elaboration

Based on the results shown in Figure 3, it can be seen that in most countries there were minimal changes in efficiency, but towards its deterioration between 2010 and 2020. The most significant decrease in efficiency was recorded by Bulgaria, which is in the last place in both years, with a country that, despite insufficient environmental efficiency, has no problem with high greenhouse gas emissions and achieving the set climate goals. The highest value of efficiency is achieved by Ireland and Luxembourg, which paradoxically belong to the countries with above-average production of greenhouse gases and at the same time did not reach the goal set in 2020 of the Europe 2020 strategy.

Table 1 shows the development of average or median values in the monitored period divided into three time intervals, namely the years 2010-2014, 2015-2020 and 2010-2020.

Table 1. Results of environmental efficiency in EU member countries

Country	Average (2010-2014)	Median (2010-2014)	Average (2015-2020)	Median (2000-2014)	Average (2010-2020)	Median (2010-2020)
SE	1.000	1.000	1.000	1.000	1.000	1.000
LU	1.000	1.000	1.000	1.000	1.000	1.000
IE	1.000	1.000	1.000	1.000	1.000	1.000
NL	0.996	1.000	0.983	0.980	0.989	0.990
DK	1.000	1.000	0.997	1.000	0.998	1.000
DE	0.998	1.000	0.970	0.970	0.983	0.970
FR	0.968	0.970	0.967	0.970	0.967	0.970

BE	0.956	0.960	0.960	0.960	0.958	0.960
IT	0.986	0.980	0.962	0.965	0.973	0.970
AT	0.962	0.970	0.945	0.945	0.953	0.950
MT	0.924	0.920	0.952	0.950	0.939	0.940
FI	0.896	0.900	0.898	0.900	0.897	0.900
CY	0.892	0.890	0.868	0.870	0.879	0.870
SI	0.816	0.820	0.827	0.820	0.822	0.820
ES	0.906	0.900	0.873	0.875	0.888	0.890
SK	0.894	0.880	0.838	0.840	0.864	0.850
PT	0.838	0.830	0.808	0.810	0.822	0.820
LV	0.976	1.000	0.847	0.865	0.905	0.900
HU	0.762	0.760	0.743	0.740	0.752	0.750
CZ	0.752	0.740	0.733	0.730	0.742	0.730
RO	0.698	0.690	0.758	0.770	0.731	0.740
LT	0.862	0.880	0.797	0.805	0.826	0.820
EE	0.720	0.660	0.628	0.630	0.670	0.640
HR	0.764	0.770	0.742	0.755	0.752	0.760
EL	0.672	0.670	0.660	0.660	0.665	0.660
PL	0.600	0.590	0.587	0.590	0.593	0.590
BG	0.388	0.400	0.312	0.315	0.346	0.320

Source: Own elaboration

During the monitored periods, there were slight changes in environmental efficiency. Deterioration of efficiency took place from 2010-2014 to 2015-2020 in most cases both in average and median values in 19 EU countries, while more significant drops in efficiency were achieved in countries at the bottom of the ranking such as Bulgaria, Estonia, Lithuania, but also the Czech Republic and Hungary. More significant declines were also recorded in Italy and Austria, which are among the countries with high environmental efficiency.

The average and median values for the observed period of 2010-2020 showed that the countries with the best environmental efficiency are Sweden, Luxembourg, Ireland and Denmark, which reached a value of 1. The countries with a low environmental efficiency below 0.7 were classified as such as Estonia, Greece, Poland and Bulgaria.

Table 2 presents a comparison of the results of environmental efficiency with an emphasis on the achievement of the GHG target and the classification of the country according to the time of accession to the EU.

Table 2. Evaluation of the success of achieving climate goals and environmental efficiency

Country	Average efficiency (2010-2020)	Ranking	Entry to EU after 2004	Achieving the goal of the Europe 2020 Strategy
SE	1.000	1	no	yes
LU	1.000	2	no	no
IE	1.000	3	no	no
DK	0.990	4	no	yes
NL	0.989	5	no	yes
DE	0.986	6	no	yes
IT	0.974	7	no	yes
FR	0.968	8	no	yes
BE	0.961	9	no	yes
AT	0.953	10	no	no
MT	0.939	11	yes	yes
LV	0.905	12	yes	yes
FI	0.902	13	no	yes
ES	0.888	14	no	no
CY	0.879	15	no	no
SK	0.864	16	yes	yes
LT	0.826	17	yes	yes
SI	0.822	18	yes	yes
PT	0.822	19	no	yes
HU	0.756	20	yes	yes
CZ	0.754	21	yes	yes
HR	0.752	22	yes	yes
RO	0.731	23	yes	yes
EL	0.727	24	no	yes
EE	0.671	25	yes	yes
PL	0.593	26	yes	yes
BL	0.346	27	yes	yes

Source: Own elaboration

The assessment of environmental efficiency pointed to significant differences between member countries that persisted throughout the duration of the Europe 2020 strategy. This confirms the difference in the approach of individual countries to the issue of climate protection. It showed that the countries with the best efficiency

include the old member states, but they also showed the problem of achieving the set climate target of GHG reduction in the case of only five countries such as Ireland, Luxembourg, Austria, Cyprus and Spain. These are countries that, in terms of GHG production, are among the largest producers of greenhouse gas emissions, and therefore their efforts to achieve the set climate goals must be significantly more intensive than among the countries that joined the EU after 2004 and are among the smallest producers of GHG in the EU. On the other hand, countries such as Bulgaria, Poland and Estonia achieved the worst efficiency, with Bulgaria achieving significantly lower results at 0.346 compared to second-to-last Poland (0.593), which may be due to its late entry into the EU. Despite the weak results of the DEA analysis, Bulgaria has been among the countries with the lowest GHG production in the EU for a long time, which does not motivate it to take significant measures in this area. The low efficiency of these countries must again be seen in the context of the set and observed climate goals, since, as mentioned, up to eleven new EU member countries had the opportunity to increase emissions compared to 1990.

On the basis of the performed analysis, it is possible to evaluate the established hypotheses. Hypothesis H1, which says that the environmental efficiency of the member countries is approaching over time, must be rejected, as it was clearly demonstrated that even during the ten years of the strategy, there was no significant convergence of the EU countries. The conditions for rejecting hypothesis H2 were also met: that states that have not met the climate goal of reducing greenhouse gases have low environmental efficiency. On the contrary, it was proven that countries that did not meet the given goal have a high level of environmental efficiency.

Conclusion

The assessment of the environmental efficiency of the EU member states is currently an interesting topic for both nature protection and environmental policymakers, whose task is to adopt meaningful measures with a positive impact on the environment. During its existence, the European Union developed and applied several strategies aimed at improving the impact of economic activity on the environment. One of the last completed initiatives is the Europe 2020 strategy, which was devoted to climate protection with the goal of reducing GHG by 20% by 2020 compared to 1990. The available data make it possible to evaluate the success of the set goals as well as to monitor the environmental efficiency in achieving the given goals, which was the subject of the presented studies.

The chosen methods made it possible to reach the conclusion that up to five countries, such as Ireland, Luxembourg, Cyprus, Spain and Austria, failed to meet the set climate goal by 2020. The main source of GHGs in Ireland is the transport, household and industrial sectors. The country shows the highest national share due to large-scale emissions from the agricultural sector in the EU agri-food production (Uidhir et al., 2020). This is 32.7% of emissions, which is three times more than in the rest of Europe. In the case of Austria, the largest share of total greenhouse gas emissions was recorded by the transport sector (up to 30%). On the other hand,

energy represented only 13% of the total share of emissions (Jensen and Fachada, 2021). In countries such as Spain and Cyprus, the largest source of GHG is tourism, which forms a significant part of the economy of these countries. Its radical limitation would thus have a significant impact on the fall in GDP.

The presented study assumed that countries that did not reach the set goal have low environmental efficiency. However, this turned out to be a false assumption and countries like Ireland and Luxembourg were included among the states with the highest environmental efficiency. Due to the high production of GHG, these countries have to make a significantly greater effort in achieving the environmental goals. However, the results of the DEA analysis were in line with existing studies such as Beltrán-Esteve et al. (2019), Matsumoto et al. (2020), Sanz-Díaz et al. (2017), Zhu et al. (2022), which draw attention to significant differences in efficiency between old and new member countries. The result of the study by Puertas et al was also confirmed. (2022), which says that Eastern European countries, which form a buffer zone against non-member countries that do not have such strict environmental policy goals as the EU, achieve less efficiency. The presented study did not show that in the monitored period there is a significant convergence of the EU countries in the area of environmental efficiency, on the contrary, the development stagnates over time.

We can use the achieved results as an explanation of the relationship between low GHG production and low environmental efficiency. Based on the analysis of the EU countries, it can be argued that the states that have been producing low GHG values for a long time, which at the EU level were the countries joining after 2004, have no significant interest in adopting measures that would lead to an increase in environmental efficiency. The environmental behavior of citizens and companies in these countries is not the highest priority for the government, even though many of them motivate the private sector to green management. However, this may lead in the future to the fact that these countries begin to lag behind in innovative approaches such as applying the principles of the circular economy, improving waste management, switching to renewable energy sources or significantly high energy consumption. The presented study offered a view of the issue only from the position of achieving one climate goal, but it is a complex problem that cannot be seen only in isolation. For this reason, there is room for further analysis that would also focus on the other goals of the Europe 2020 strategy, which can already be evaluated, or monitored in the context of the new challenges of the 2030 Agenda.

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EFETYWNOŚĆ ŚRODOWISKOWA W KONTEKŚCIE REALIZACJI CELÓW KLIMATYCZNYCH UE

Streszczenie: Unia Europejska aktywnie uczestniczy w walce ze zmianami klimatycznymi, ustanawiając krajowe i międzynarodowe cele w dziedzinie ochrony środowiska. Ważnym i globalnie monitorowanym wskaźnikiem jest emisja gazów cieplarnianych netto (GHG), których redukcja została uwzględniona w Strategii Europa 2020 i jest przedmiotem Agendy 2030. Niniejszy artykuł skupia się na ocenie realizacji głównego celu klimatycznego ustanowionego w Strategii 2020 oraz analizie efektywności środowiskowej państw członkowskich w redukcji emisji gazów cieplarnianych netto (GHG). Do oceny wyznaczonego celu klimatycznego zastosowano metodę odległości od obiektu fikcyjnego, a efektywność środowiskową mierzono w okresie 2010-2020 za pomocą metody DEA. Wybrane metody pozwoliły dojść do wniosku, że do 2020 roku pięć krajów, takich jak Irlandia, Luksemburg, Cypr, Hiszpania i Austria, nie osiągnęło wyznaczonego celu klimatycznego. Za pomocą metody DEA wykryto istotne różnice w efektywności środowiskowej między krajami, które przystąpiły do UE przed i po 2004 roku. Niższą efektywność środowiskową osiągnięto w większym stopniu przez kraje, które przystąpiły do UE w ostatnim przedziale czasowym. Przedstawione badanie założyło, że kraje, które nie osiągnęły wyznaczonego celu, mają niską efektywność środowiskową. Jednak okazało się, że jest to fałszywe założenie, a kraje takie jak Irlandia i Luksemburg zostały uwzględnione wśród państw o najwyższej efektywności środowiskowej. Wyniki mogą wskazywać, że cele klimatyczne na poziomie krajowym zostały ustawione zbyt ambitnie w tych krajach.

Słowa kluczowe: efektywność środowiskowa, zachowanie środowiskowe, zarządzanie ekologiczne, DEA, GHG, Strategia Europa 2020