Greenhouse Gas Emissions in the EU - The Current Situation and Significant Statistical Relations

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Abstract: The increase in greenhouse gas emissions has become a significant problem for the people and the environment. As a signatory party of the Kyoto Protocol and Paris Agreement, the European Union joined the international community's efforts to achieve a 20% cut in greenhouse gas emissions by 2020 compared to 1990 levels and up to 55% by 2030 as intermediary stages towards achieving climate neutrality by 2050. Recent studies revealed that limiting global warming to 1.5 degrees Celsius to meet the Paris Agreement requirements will still be difficult under the current level of ambition.
This paper aims to assess the progress registered by the EU member states in meeting the climate targets assumed according to the newest EU goals in the field.
It also aims to identify levers that can help meet these objectives by analysing their relationships with greenhouse gas emissions. Our research looks for potential relations between the greenhouse gas emissions and the following indicators: life expectancy, gross domestic product, final energy consumption, final energy consumption in transport, utilised agricultural area and manufacturing value-added. To this end, this paper employs scatter plots to check for linearity, calculates the Pearson's r correlation coefficient for each analysed pair and tests them at a 95% confidence level to establish the statistical significance.
Five statistically significant linear relationships at a 95% confidence level between the GHG emissions and the following indicators have been identified: life expectancy, gross domestic product, manufacturing value-added, utilised agricultural area and final energy consumption. Therefore, the decision-makers could take measures to address these levers to cut emissions at the desired level. The research is based on the literature and the data provided by Eurostat and the World Bank.

Key-Words: emissions reduction, climate, significant correlations, life expectancy, transport

JEL Classification: C1, O13, Q5.

1 Introduction

Greenhouse gases (GHG) are gasses that trap the heat in the atmosphere, thus contributing to global warming. Carbon dioxide (CO2) has the highest share of GHG emissions (76%). The burning processes and some specific chemical reactions generate most carbon dioxide emissions. The plants absorb CO2 during the photosynthesis process and generate it during the oxidation process but to a lesser extent. Therefore, preserving biodiversity and green areas is crucial in our efforts to decrease greenhouse gas emissions, naturally, as per Kyoto and Paris documents (Change, 2014).

Methane`s share in GHG emissions is 16%. Fossil fuels, livestock, agricultural practices and the decay of organic waste are the primary sources of methane emissions.

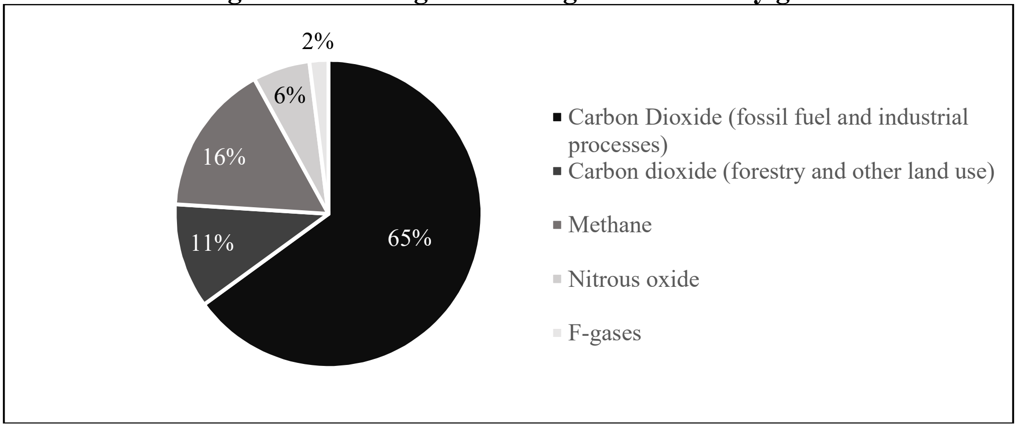
Nitrous oxide has a minor contribution to GHG emissions, only 6%. Agricultural and industrial activities, the combustion of fossil fuels and solid waste, and wastewater treatment are responsible for most nitrous oxide emissions (EPA, 2020).

Therefore, the primary sources of GHG are the burning processes, the production and transport of fossil fuels, agricultural and industrial activities and specific chemical industrial reactions, agricultural practices, and waste.

In order to cut these emissions, the decision-makers have to address the primary sources of GHG and to identify ways to turn the respective economic activities more sustainably.

The 2020 global Living Planet Index shows that between 1970 and 2016, the monitored populations of mammals, birds, amphibians, reptiles and fish recorded an average fall of 68%. Approximately 22% of the plants are threatened with extinction, most in the tropics. Human activities altered most of the land surface, polluted the oceans, and destroyed almost all wetlands (WWF, 2020).

Figure 1. Global greenhouse gas emissions by gas



Source: EPA (2021).

The annual global temperature is likely to be at least one degree Celsius warmer than preindustrial levels in the coming five years. It is very likely to be within the range of 0.91 – 1.59°C. (WMO, 2020).

The Biodiversity Ecosystem Services (BES) Index shows that 20% of all countries have ecosystems in a fragile state for more than 30% of their territory. Furthermore, 55% of global GDP is moderately or highly dependent on BES. The impact on financial assets is also enormous: The Dutch National Bank estimates a staggering EUR 510 billion, or 36% of all of the investments from Dutch financial institutions, would be lost if the ecosystem services underpinning the Dutch economy were no longer available (Swiss RE Institute, 2020).

2 Literature review

There are several important studies on the topic of this paper. Rafaj et al. (2011) analysed the impact of air pollution on life expectancy in Europe, China and India. They found that in China, current ambient concentrations of PM2.5 are responsible for 38 months-losses in the average life expectancy. Farchi et al. (2017) provide evidence supporting a reduction in red meat consumption toward the Mediterranean target of 150 grams/week per capita. A Mediterranean diet model would save 5 million years of life lost prematurely among men and women over the next 18 years and increase the average life expectancy of future generations by over seven months. Therefore, less meat means les methane released into the atmosphere and healthier people.

Tucker (1995) identified a positive relationship between carbon dioxide emissions and the GDP and found that, in general, as per capita income grows, the increase in the emissions tends to decelerate. He argued that higher income levels might lead to increased demand for environmental protection. In China's case, Cohen et al. (2019) showed that emissions go up more during booms than they decline during busts.

According to the empirical findings, Hamit-Haggar (2012) suggests that energy consumption has a positive and statistically significant impact on GHG emissions in the long-run equilibrium.

Matthew et al. (2018) observed that carbon dioxide emission is the primary source of GHG emissions; therefore, the study posits that cuts in carbon dioxide emissions would improve health outcomes in Nigeria. These cuts may be done by reducing deforestation and conservation of land, controlling wildfire, adopting better methods of combusting residues of crops, and effective use of energy by forest dwellers, amongst other measures.

Khan et al. (2014) found that energy consumption is closely connected with greenhouse gas emissions, and carbon dioxide emissions exert the most extensive influence on changes in energy consumption in different regions of the world.

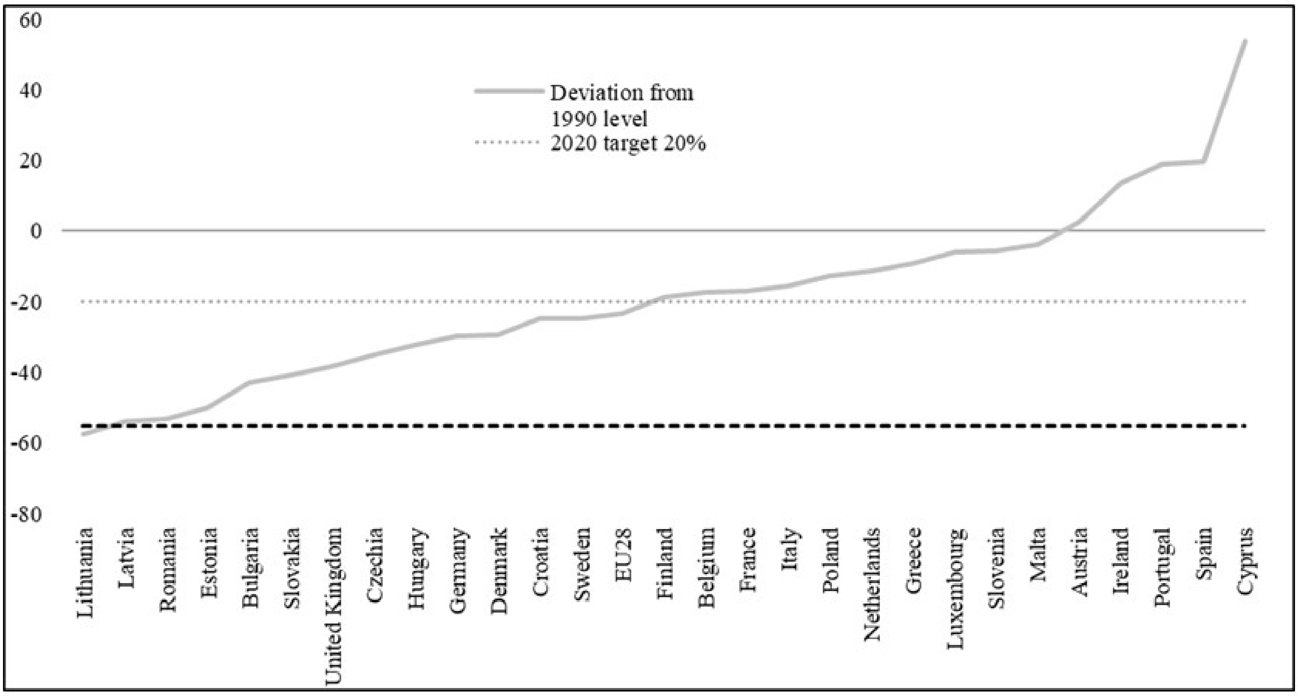
Hong et al. (2014) show that material manufacturing, transportation, and on-site construction were responsible for 94.89%, 1.08%, and 4.03% of energy consumption, and 95.16%, 1.76%, 3.08% of global warming potential, respectively.

Smith et al. (2008) emphasise that agriculture accounts for 52% and 84% of global anthropogenic methane and nitrous oxide emissions. Frank et al. (2017) argue that agriculture will have to contribute to efforts to decrease GHG emissions, thus keeping global warming below 1.5 degrees Celsius and mitigating adverse effects of climate change. Climate stabilisation without compromising food security requires an intelligent climate policy design that enables GHG-efficient mitigation in agriculture, forestry, and other land use. Considering the environmental impact, emissions associated with the actual total intake of beef range from 12,900 to 21,800 GHG CO2 equivalent; emissions saved according to the Mediterranean scenario are in the range of 8,000–14,000 GHG CO2 equivalent per year (Farchi et al., 2017).

3. Greenhouse gas emissions in the EU - the current situation

According to the statistical data provided by Eurostat (Figure 2), Lithuania, Latvia, Romania, Estonia, Bulgaria, Slovakia, United Kingdom, Czechia, Hungary, Germany, Denmark, Croatia, and Sweden met two years before the target for 2020 (a reduction by 20% in the emissions of GHG, as compared to the levels in 1990.

Figure 2. The decrease in GHG emissions in 2018 as compared to 1990, and the positioning against the targets for 2020 and 2030 (20%, 40% and 55%), in %



Source: Author's own representation, based on Eurostat (2020).

In the case of Lithuania, Latvia, Romania, Estonia and Slovakia, the former target for 2030, namely 40%, has also been met since 2018. The rest of the EU countries position themselves below the set level of ambition.

Under the new level of ambition of 55%, Lithuania is the only EU country that has already met that target since 2018. The rest of the states have to take significant measures to align with the EU targets.

From the perspective of greenhouse gas emissions as tonnes per capita (Figure 3), between 1990 and 2018, the most significant decrease was registered by the United Kingdom, by 47%, from 14 tonnes per capita to 7.5 tonnes per capita, followed by Romania (a drop of 44%), from 11 tonnes to 6 tonnes and Lithuania (44%), from 13 tonnes to 7 tonnes.

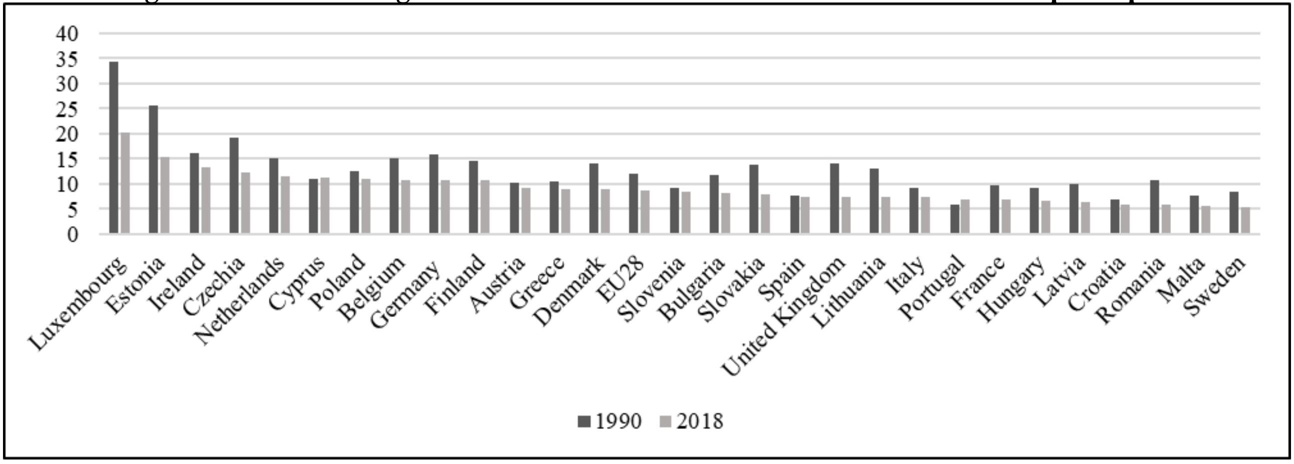
These countries rank way below the average decrease in the EU of 28%. During the analysed interval, performances above the EU average regarding the percentage decrease were registered by Denmark (-37%), Germany (-33%) and Sweden (-36%).

Compared to 1990, Portugal was the only country that has recorded a significant increase in GHG emissions per capita (+17%), followed by Cyprus with a rise of only +2%.

Still, in 2018, Germany emitted almost 11 tonnes of GHG per capita, the equivalent of Romania`s emissions in 1990.

In 2018, the emissions champions were Luxembourg (20 tonnes per capita), Estonia (15 tonnes per capita) and Ireland (13 tonnes per capita). The lowest emissions of GHG per capita were registered in Romania (6 tonnes), Malta (5.5 tonnes) and Sweden (5.4 tonnes of GHG emissions per capita).

Figure 3. Greenhouse gas emissions in the EU28 in 1990 and 2018 - tonnes per capita



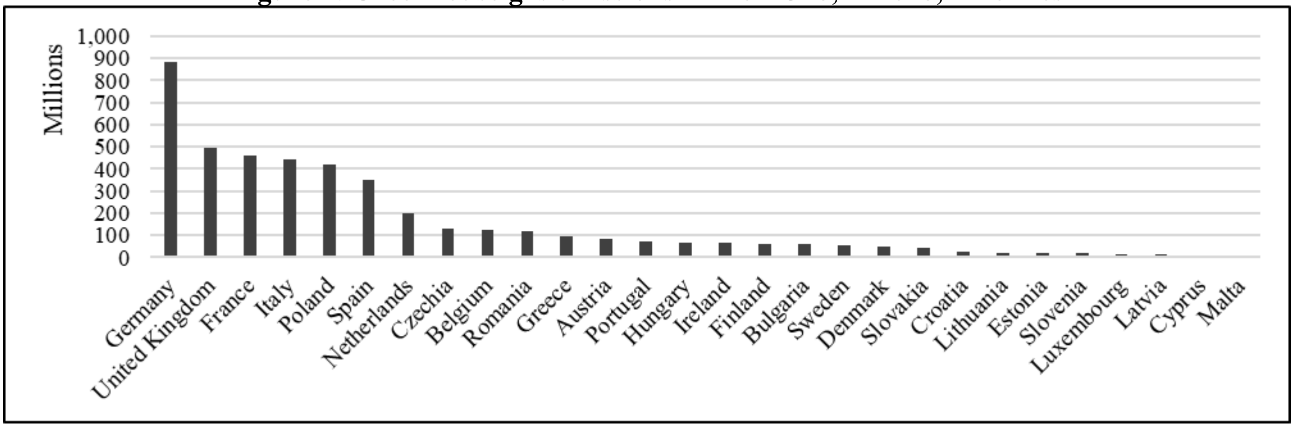
Source: Author's own representation, based on Eurostat (2020).

Regarding the emissions of GHG in tonnes (Figure 4), in 2018, Germany ranked first among the EU countries, with almost 900 million tonnes, followed by the United Kingdom with around 500 million tonnes and France with 460 million tonnes.

The last three countries in the EU regarding GHG emissions in tonnes were Latvia (12 million tonnes), Cyprus (10 million tonnes) and Malta (3 million tonnes).

Therefore, even if from the statistical point of view, the leading EU economies regarding the size of GDP, namely Germany, United Kingdom, France, Italy and Spain, recorded noteworthy progress in decreasing GHG emissions per capita, they are still the major polluters.

Figure 4. Greenhouse gas emissions in the EU28, in 2018, in tonnes



Source: Author's own representation, based on Eurostat (2020).

Among the countries in Eastern Europe, Poland ranks fifth with 417 million tonnes, Czechia the eighth with 130 million tonnes and Romania the tenth with 117 million tonnes.

According to the projections of the European Commission (2020), to meet the target of 55%, between 2021 and 2030, the EU has to invest annually approximately 126 billion euros for the energy supply sector, 22 billion euros for the industrial sector, 620 billion euros for the transport sector and 193 billion euros for the residential sector (Table 1).

Table 1. Average annual investment for the climate target, billion euros 2015

Sectors	Target 55% ALLBNK*	
	Average 2021-2030	Average 2031-2050
Investments in power grid	60.10	80.30
Investments in power plants	59.60	85.40
Investments in boilers	4.60	1.40
Investments in new fuels production and distribution	2.20	25.90

Sectors	Target 55% ALLBNK*	
	Average 2021-2030	Average 2031-2050
Total supply side investments	126.40	193.00
Industrial sector investments	21.90	14.80
Residential sector investments	193.10	176.10
Tertiary sector investments	92.90	86.00
Transport sector investments	620.30	726.00
Total demand side investments	928.20	1,003.00
Total demand side investments excl. transport	307.90	277.00
Total energy system investments	1,054.70	1,196.00
Total energy system investments excl. transport	434.30	470.00

Source: European Commission (2020).
*ALLBNK is the most ambitious scenario in GHG emissions reduction based on MIX and further intensifying fuel mandates for aviation and maritime sectors in response to the extended scope of GHG reductions covering all aviation and navigation.

4. Greenhouse gas emissions in the EU - significant statistical relations

The first step in analysing the relationship between the chosen pairs of variables was to draw the scatter plots of linearity based on the data from Table 2. With one exception, namely the relationship with life expectancy, greenhouse gas emissions were considered a dependent variable and the rest were independent variables.

Table 2. Synoptic table of the analysed indicators

Year	GHG emissions tonnes per capita (GHG)	GDP current euro per capita (GDP)	Utilised agricultural area Main area (1000 ha) (UAA)	Life expectancy Years (LE)	Manufacturing, value added current US$** (MVA)	Final energy consumption Million (TOE)* (FEC)	Final energy consumption in transport Thousand (TOE) (FECT)
1991	11.8	:	:	:	1,330,694,467,745.7	:	:
1992	11.4	:	:	:	1,407,795,158,019.9	:	:
1993	11.2	:	:	:	1,228,940,853,847.6	:	:
1994	11.1	:	:	:	1,292,938,408,296.5	:	:
1995	11.2	:	:	:	1,500,745,505,031.1	:	:
1996	11.4	:	:	:	1,492,388,768,009.4	:	:
1997	11.2	:	:	:	1,374,331,796,774.2	:	:
1998	11.1	:	:	:	1,416,763,231,928.9	:	:
1999	10.9	:	:	:	1,379,254,754,871.4	:	:
2000	10.8	:	:	:	1,272,273,050,781.2	1,133.3	:
2001	10.9	:	:	:	1,271,129,223,084.6	1,157.8	:
2002	10.8	:	:	:	1,348,031,810,434.2	1,145.8	:
2003	11.0	:	:	:	1,618,611,070,804.2	1,177.6	:
2004	10.9	:	:	:	1,840,027,778,566.8	1,189.6	:
2005	10.8	:	:	:	1,889,224,483,523.4	1,193.8	:
2006	10.8	:	:	78.9	2,011,405,428,652.9	1,197	:
2007	10.7	:	:	79.1	2,335,137,032,996.6	1,177.4	336,085.963
2008	10.4	26,130	182,807.8	79.4	2,482,423,907,762.0	1,184.8	330,269.715
2009	9.6	24,530	181,472.1	79.6	2,043,538,571,554.0	1,118.6	321,661.108

2010	9.8	25,500	180,136.8	79.9	2,106,279,556,840.3	1,166.7	320,500.622
2011	9.5	26,220	179,365.4	80.2	2,326,082,209,776.2	1,114.2	318,951.192
2012	9.3	26,680	178,197.8	80.3	2,135,253,062,539.2	1,115.7	308,965.43
2013	9.1	26,850	178,098.8	80.5	2,218,551,916,831.8	1,115.5	305,178.918
2014	8.7	27,730	178,392.7	80.9	2,301,232,633,700.3	1,067.6	309,287.354
2015	8.8	29,140	178,995.6	80.6	2,073,645,013,012.3	1,090.1	313,633.566
2016	8.7	29,310	178,750.9	81.0	2,141,509,351,373.1	1,110	321,020.086
2017	8.8	30,090	178,822.2	80.9	2,263,942,742,149.0	1,122.9	326,918.011
2018	8.6	31,000	179,144.6	81.0	2,433,238,416,899.9	1,124.1	328,590.674

* Tonnes of oil equivalent
Source: European Commission, World Bank** (2020).

The resulted scatter plots are displayed in the figures from 5 to 10. The nearer the scatter points are to a straight line, the higher the association between the variables.

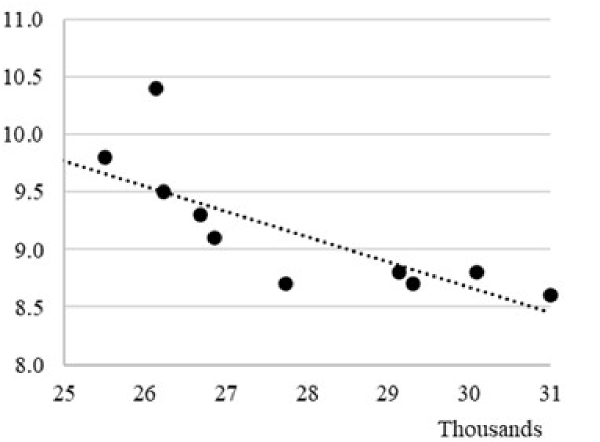


Figure 5. The relationship between GHG emissions (tonnes per capita) (Y) and GDP per capita (X)

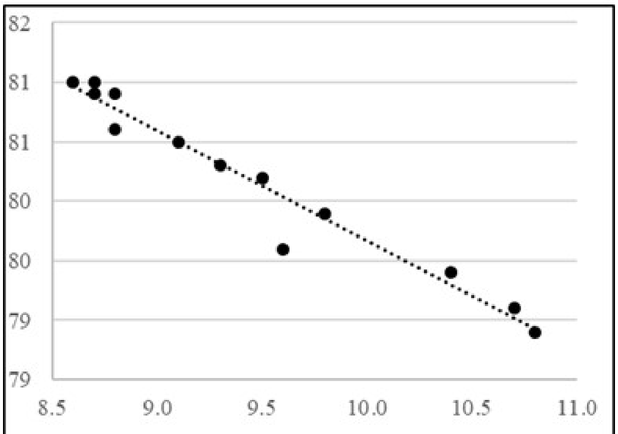


Figure 6. The relationship between the life expectancy (Y) and GHG emissions (tonnes per capita) (X)

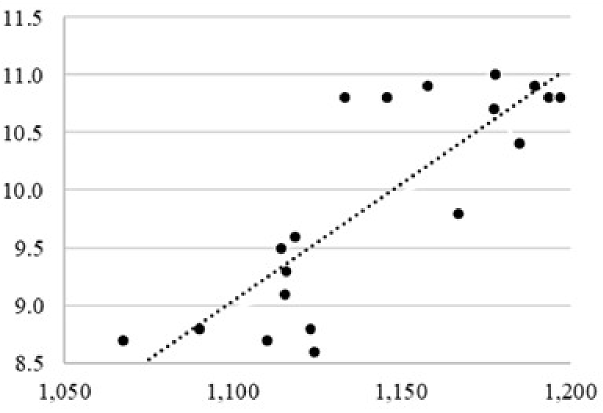


Figure 7. The relationship between GHG emissions (tonnes per capita) (Y) and final energy consumption (X)

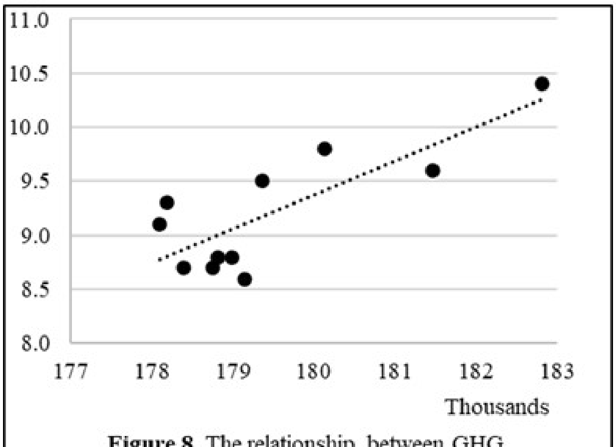


Figure 8. The relationship between GHG emissions (tonnes per capita) (Y) and utilised agricultural area (X)

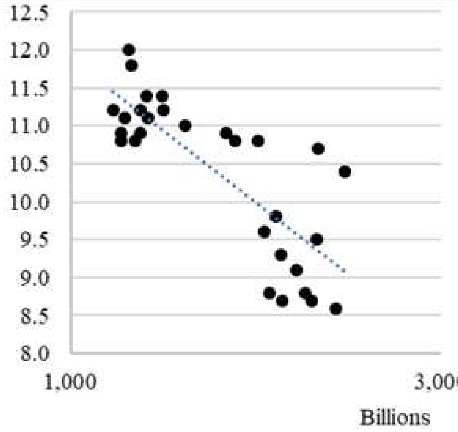


Figure 9. The relationship between GHG emissions (tonnes per capita) (Y) and manufacturing value added (X)

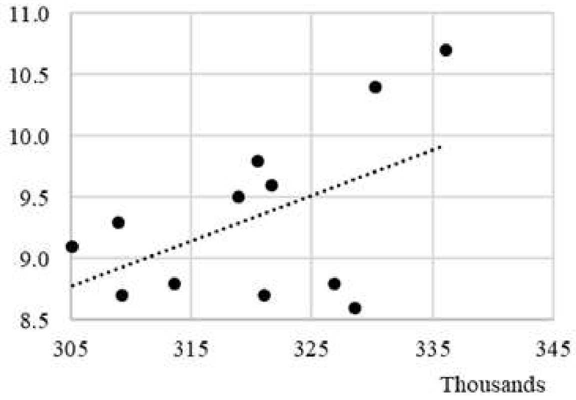


Figure 10. The relationship between GHG emissions (tonnes per capita) (Y) and Final energy consumption in transport (X)

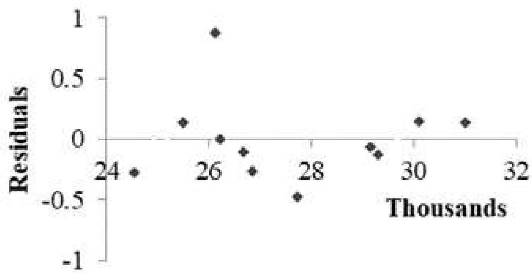


Figure 11. GDP per capita Residual Plot

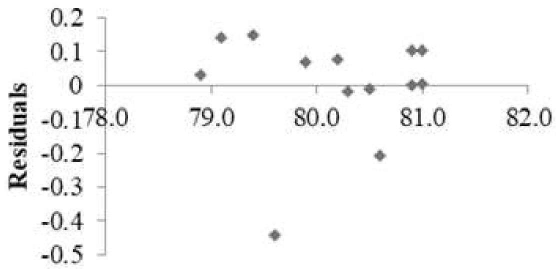


Figure 12. GHG emissions Residual Plot

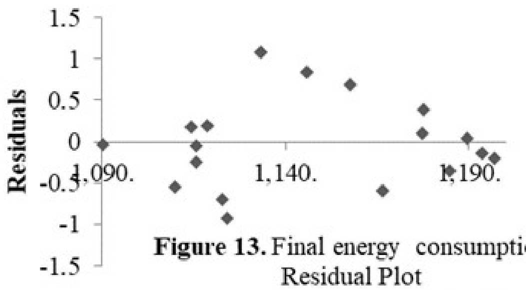


Figure 13. Final energy consumption Residual Plot

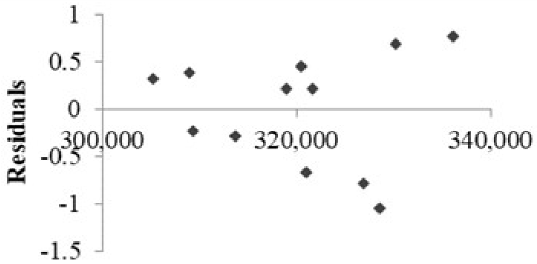


Figure 14. Final energy consumption in transport - Residual Plot

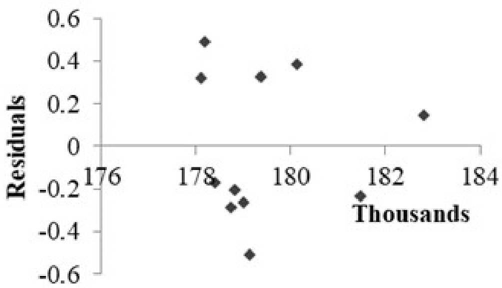


Figure 15. Utilised Agricultural Area Residual Plot

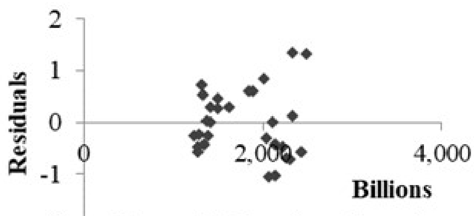


Figure 16. Manufacturing, value-added Residual Plot

The residual plots display somewhat random patterns that indicate that linear models provide a decent fit to the data. The sample Pearson`s r is calculated with the following formula:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}\ \sqrt{n\sum y^2 - (\sum y)^2}} \quad (1)$$

Using Microsoft Excel, we calculated the value of Pearson`s r for the analysed data.

Table 3. Correlation coefficient and coefficients of determination between GHG emissions (GHGE) and the selected independent variables

Indicator	GDP	LE	FEC	UAA	MVA	FECT
Correlation coefficient	-0.788512832	-0.978072905	0.826897523	0.804266832	-0.794072287	0.509428296
Coefficient of determination	0.621752487	0.956626608	0.683759513	0.646845137	0.630550797	0.259517189

The values of the r coefficient indicate that there are uphill solid linear relationships ($r>0.70$) between the GHG emissions and final energy consumption and between GHG emissions and utilised agricultural land. Therefore, the dependent and independent variables increase together.

We also found three strong negative linear relationships between GHG emissions and GDP, GHG emissions and Life expectancy and between GHG emissions and Manufacturing value-added. As one variable increases, the other one decreases, and vice versa.

The coefficients of determination (r^2) vary from 0.9566 (GHGE/LE) to 0.2595 (GHGE/FECT). That means that the relationship between the analysed variables explains between 95.66% and 25.95% of the variation in GHG emissions. It does not mean that one variable causes the other in any relationship.

The pairs of variables are tested at a 95% level of confidence to identify if their linear relationships are statistically significant.

The null hypothesis (H0) implies no statistically significant linear relationship in the EU between GHG emissions (tonnes per capita) and GDP or LE or FEC or UAA or MVA, or FECT.

The alternate hypothesis (Ha) implies a statistically significant linear relationship in the EU between GHG emissions (tonnes per capita) and the selected independent variables.

H0: $\rho = 0$.

Ha: $\rho \neq 0$.

While Pearson`s r is the sample correlation coefficient, ρ is the population correlation coefficient. The hypotheses were tested using the t-distribution.

Calculations:

Having a two-tailed test, and $\alpha = 0.05$, the value of $\alpha/2 = 0.025$. The critical value of t that gives the area of 0.025 to the right tail of the t-distribution has to be found.

The t-distribution table was used to find the value of $t_{0.025}$. Taking into consideration the degree of freedom and the level of significance α (Table 4). Since the t-distribution is symmetrical, $-t_{\alpha/2} = -t_{0.025}$ (the value of t that gives the area of 0.025 to the left of the t-distribution).

We calculate the test statistic t using the formula:

$$t = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}} \quad (2)$$

Table 4. T-Distribution indicators for our analysed pairs of variables

	GHGE/GDP	LE/GHGE	GHGE/FEC	GHGE/UAA	GHGE/MVA	GHGE/FECT
Number of observations (n)	11	13	19	11	29	12
Degree of freedom (Dof)	9	11	17	9	27	10
$t_{0.025}$	2.262	2.201	2.110	2.262	2.052	2.228
$-t_{0.025}$	-2.262	-2.201	-2.110	-2.262	-2.052	-2.228
Test statistic **t**	-3.846	-15.575	6.062	4.060	-6.788	1.872

	GHGE/GDP	LE/GHGE	GHGE/FEC	GHGE/UAA	GHGE/MVA	GHGE/FECT
$t < -t_{0.025}$ or $t > t_{0.025}$	yes	yes	yes	yes	yes	no
Statistical significance	We reject (H0). We are 95% confident that there is a statistically significant linear relationship between GHG emissions and GDP.	We reject (H0). We are 95% confident that there is a statistically significant linear relationship between the life expectancy and GHG emissions.	We reject (H0). We are 95% confident that there is a statistically significant linear relationship between the GHG emissions and the final energy consumption.	We reject (H0). We are 95% confident that there is a statistically significant linear relationship between the GHG emissions and the utilised agricultural area.	We reject (H0). We are 95% confident that there is a statistically significant linear relationship between the GHG emissions and the manufacturing value-added.	We fail to reject H0. There is no statistically significant linear relationship in the EU between GHG emissions and the final energy consumption in transport.

4 Conclusion

By trapping the heat in the atmosphere, GHG emissions significantly impact global warming, making the reduction of such emissions a significant topic on the EU Commission agenda. Therefore, the climate targets as they were set should be met by all member states accordingly. Thirteen EU countries met the target for 2020 back in 2018. Five European countries, Romania included, have met the previous target for 2030 since 2018; therefore, for these countries, reaching a 55% or even a 60% cut in GHG emissions by 2030 could be easier to achieve.

Even if the leading EU economies recorded significant cuts in GHG emissions per capita between 1990 and 2018, Germany, France, Italy and Spain remain the highest GHG emitters.

The econometrical analysis confirmed some of the findings of the studies mentioned in the literature review.

Out of six analysed relationships involving GHG emissions, five turned out to be statistically significant at a level of confidence of 95%. The highest coefficient of determination has the relationship between life expectancy and GHG emissions, explaining 95.66% of the variation in life expectancy. The relationship with the highest coefficient of determination, in which GHG emissions was the dependent variable, is the one including final energy consumption (this relationship could explain 68,37% in the variation of GHG emissions), followed by the one with the utilised agricultural area and the one with manufacturing value-added.

The econometric analysis focused on indicators that reflect the economic activities involving burning processes, production and transport of fossil fuels, agricultural and industrial activities, specific chemical reactions, agricultural practices, and waste, which are the primary sources of GHG. Thus, the decision-makers could consider the results of this analysis when creating policies to cut GHG emissions.

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