Modelling the Relationship between Final Energy Consumption, Share of Energy From Renewable Sources and Greenhouse Gases in the EU and Romania

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Abstract: - The EU has to reduce greenhouse gas emissions by 55% compared to the levels recorded in 1990 by 2030, despite the higher level of ambition suggested by the European Parliament, namely 60%. It is a very optimistic goal considering the different levels of compliance to the intermediary targets by the EU member states. Reducing energy consumption or increasing the share of green energy seems to be the directions to follow to meet the requirements set by the Commission; energy consumption is the highest generator of such gases that are detrimental to all life forms and the planet. In our paper, we are modelling the relationship between final energy consumption, greenhouse gas emissions and the share of energy from renewable sources in the EU and Romania to assess their statistical significance in order to identify how the energy sector could turn into a lever in the transition towards the green economy. We identify a strong statistically significant relationship between final energy consumption and greenhouse gas emissions in the EU27, as opposed to Romania`s case, in which the correlation coefficient is extremely weak. We also find out that the correlation between the share of energy from renewable sources and greenhouse gas emissions is stronger and more statistically significant in Romania than in the EU27, explaining somehow the first findings. For our analysis, we use the database of Eurostat and several statistical tools.

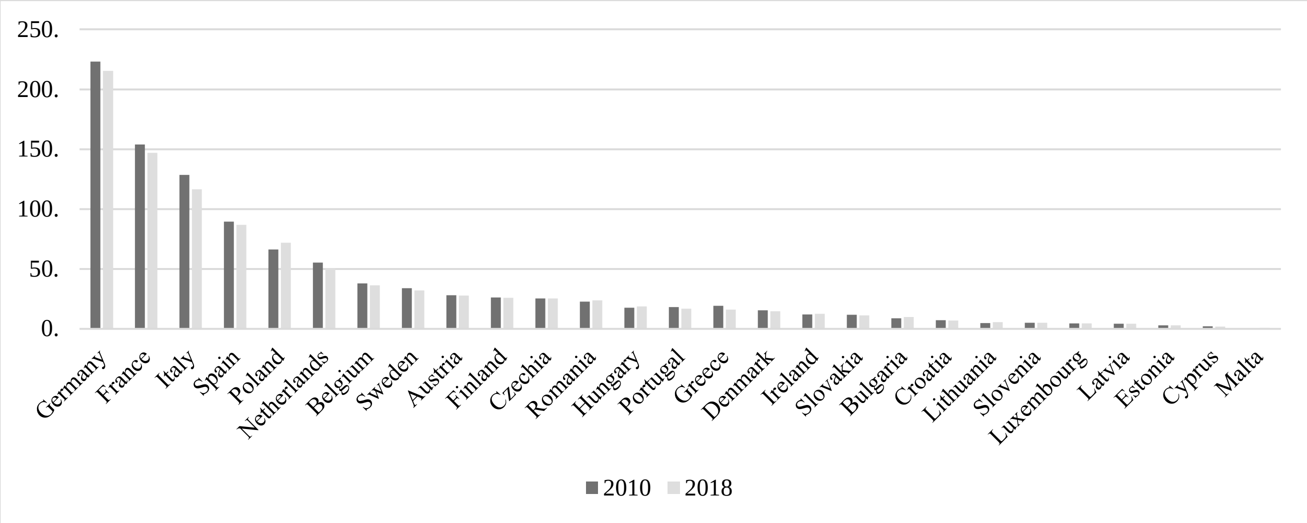
Key-Words: - renewable energy, energy consumption, greenhouse gases, correlation
JEL Classification: Q00, Q01, Q5, Q53, Q59

1 Introduction

In the EU, final energy consumption measures energy consumption levels by end-users, such as households, industry, and agriculture. It excludes the energy used by the energy sector, including for deliveries and transformation. It also excludes fuel transformed in the electrical power stations of industrial auto-producers and coke transformed into blast-furnace gas, where this is not part of overall industrial consumption but of the transformation sector (Eurostat, 2021a)

The advantages of energy efficiency are manifold. The energy-saving could improve the security of the energy supply by reducing the dependence on fuel imports. The improvement in energy efficiency also improves the competitiveness of European industry and services; for households, it reduces the energy bill. Energy-saving could also contribute to reducing greenhouse gas (GHG) emissions from fuel combustion. (Eurostat, 2021b).

Chart 1: Energy efficiency in the EU27 - Final energy consumption (Europe 2020-2030), Million tonnes of oil equivalent (TOE)



Source: Eurostat, 2021b

According to Eurostat (Chart1), between 2010 and 2018, final energy consumption decreased in the EU27 by 3.32%, 34.2 million TOE. In the majority of the EU member states (16 countries), the energy consumption decreased, but in other (10 countries) it increased. The highest percentage decrease in energy consumption was recorded by Greece (-15.42%), followed by Italy (-9.39%) and Netherlands (-8.46%).

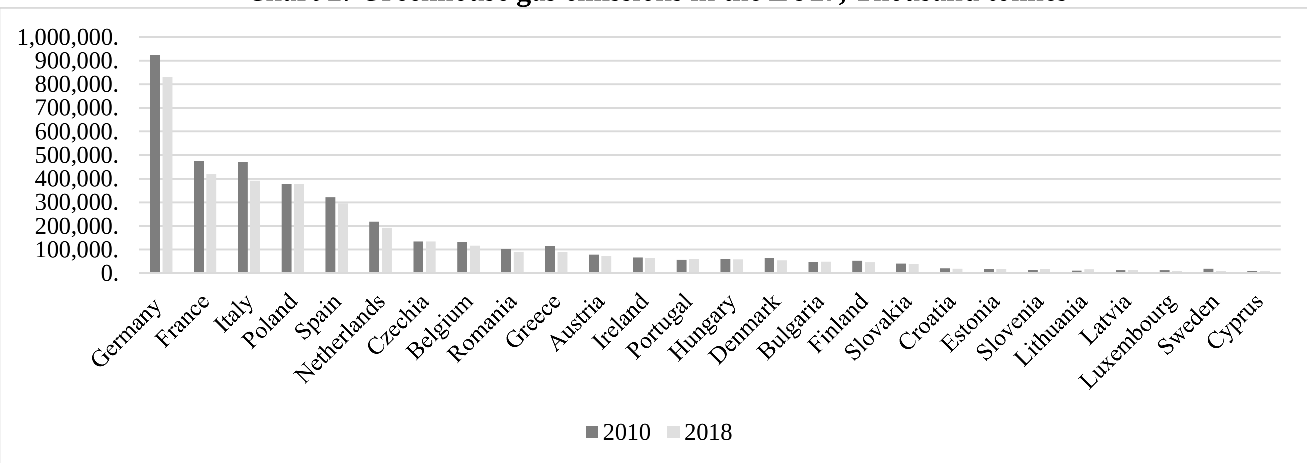
The highest percentage increase in energy consumption was registered in Malta (32.00%), followed by Lithuania (15.80%) and Bulgaria (12.23%). Romania ranked seventh (+4.66%) among the EU countries that increased energy consumption in the same timeframe.

In terms of quantity dynamic, Italy ranks first in the EU27, with a cut in final energy consumption of 12.07 million TOE, seconded by Germany (-7.56 million TOE), and France (-7.56 million TOE). The highest quantitative increase in final energy consumption was recorded in Poland (+5.57 million TOE), followed by Bulgaria (+1.08 million TOE) and Hungary (+1.06 million TOE) and Romania (+1.05).

Overall, in terms of consumption expressed in TOE in 2018, Germany was by far the EU27 leader with 215.46 million TOE (21.77% of total EU27 energy consumption, almost a quarter), followed by France (146.84 million TOE), and Italy (116.44 million TOE). Romania ranked 12^{th} (23.59 million TOE). Estonia (2.96 million TOE), Cyprus (1.86 million TOE) and Malta (0.66 million TOE) closed the EU27 hierarchy regarding final energy consumption.

According to Eurostat (2021c), the greenhouse gas emissions inventory contains data on carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3).

Chart 2: Greenhouse gas emissions in the EU27, Thousand tonnes



Source: Eurostat, 2021c

As per the data provided by Eurostat (Chart 2), between 2010 and 2018, greenhouse gas emissions decreased in the EU27 by 9.36%, 361,571.86 thousand tonnes, respectively (22 countries reduced GHG emissions). The highest percentage decrease in GHG emissions was recorded by Sweden (-49.46%), followed by Malta (-26.66%) and Greece (-22.72%). The highest percentage increase in GHG emissions was registered in Lithuania (54.68%), followed by Slovenia (32.13%) and Latvia (9.21%). Romania ranked 12th among the EU countries that decreased GHG emissions (-11.41%) in the same timeframe.

Between 2010-2018, in terms of quantity dynamic, Germany ranks first in the EU27, with a cut in GHG emissions of around 91 thousand tonnes, followed by Italy (-81 thousand tonnes) and France (-55 thousand tonnes). Romania ranks eighth among the EU countries that diminished their GHG emissions (-12 thousand tonnes. Lithuania ranks last in the EU27, with an increase in GHG emissions of 5,797.36 thousand tonnes, being followed by being Slovenia (4,315.53 thousand tonnes) and Portugal (3,381.76 thousand tonnes) in the top of the EU countries that increased their emissions.

Overall, in terms of GHG emissions, in 2018, Germany was by far the EU27 largest polluter with 831,436.95 thousand tonnes (23.74% of total EU27 GHG emissions), followed by France (419,118.49 thousand tonnes) and Italy (391,263.13 thousand tonnes). Romania ranked ninth (91,656.49 thousand tonnes). Sweden (9,785.28 thousand tonnes), Cyprus (8,411.15 thousand tonnes) and Malta (2,190.45 thousand tonnes) closed the EU27 ranking regarding GHG emissions.

2 Problem Formulation

As a methodology, based on the Eurostat database, Pearson`s r correlation coefficient is used to investigate if, in the EU27 and Romania, there is a linear relationship between final energy consumption and greenhouse gas (GHG) emissions. If there is such a relation, the goal is to find out how strong it is and test its statistical significance at a level of confidence of 95%. If there are divergent results between EU27 and Romania, the analysis introduces a new indicator, namely the share of energy from renewable sources, to explain the eventual divergence.

3 Problem Solution

The data needed to calculate the Pearson correlation coefficient (Pearson`s r) between final energy consumption and (GHG) emissions were collected from the statistical office of the European Union (Table 1).

Table 1: Final energy consumption and Greenhouse gas emissions in the EU27 and Romania between 2010 and 2018,

Year	EU27 - Final energy consumption, Million tonnes of oil equivalent (TOE)	EU27 - Greenhouse gases, Thousand tonnes	Romania - Final energy consumption, Million tonnes of oil equivalent (TOE)	Romania - Greenhouse gases, Thousand tonnes
2010	1,023.79	3,862,747.61	22.54	103,455.22
2011	984.35	3,755,309.45	22.74	109,533.32
2012	982.28	3,674,289.61	22.76	104,815.28
2013	980.29	3,588,728.61	21.80	94,683.20
2014	938.88	3,473,826.7	21.69	93,878.21
2015	958.47	3,535,584.01	21.85	94,488.55
2016	977.71	3,541,154.42	22.24	91,182.74
2017	989.66	3,601,730.63	23.33	95,195.44
2018	989.77	3,501,175.75	23.59	91,656.49

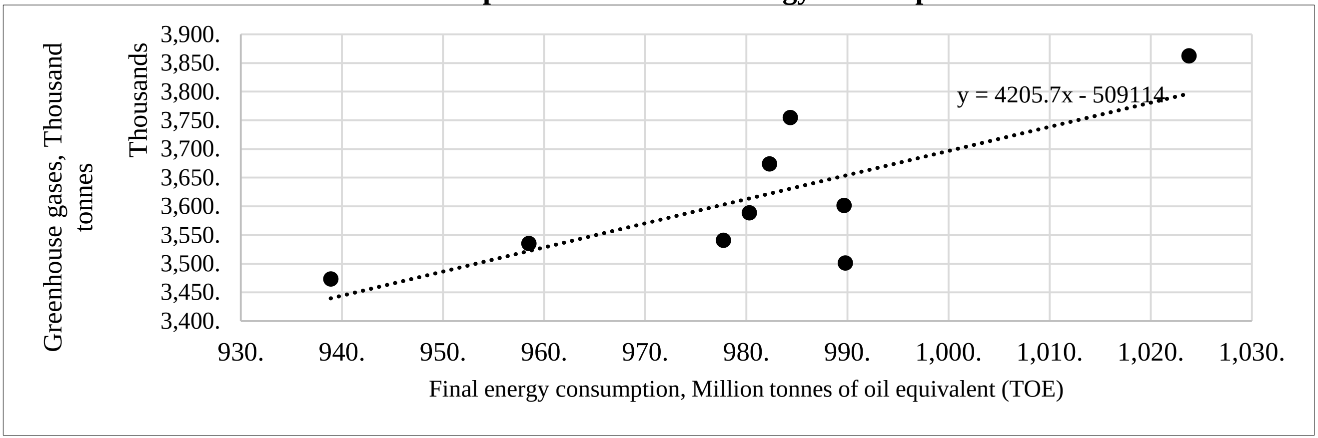
Source: Author`s based on data provided by Eurostat (2020b).

The sample Pearson`s r is calculated with the following formula (1):

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

Using Microsoft Excel, we calculated the value of Pearson`s r for the EU27 data. The value of r is 0.763487. It means that there is a strong linear relationship between the analysed indicators, with a positive slope. Therefore, if one indicator increases, the other one increases too (See Chart 3).

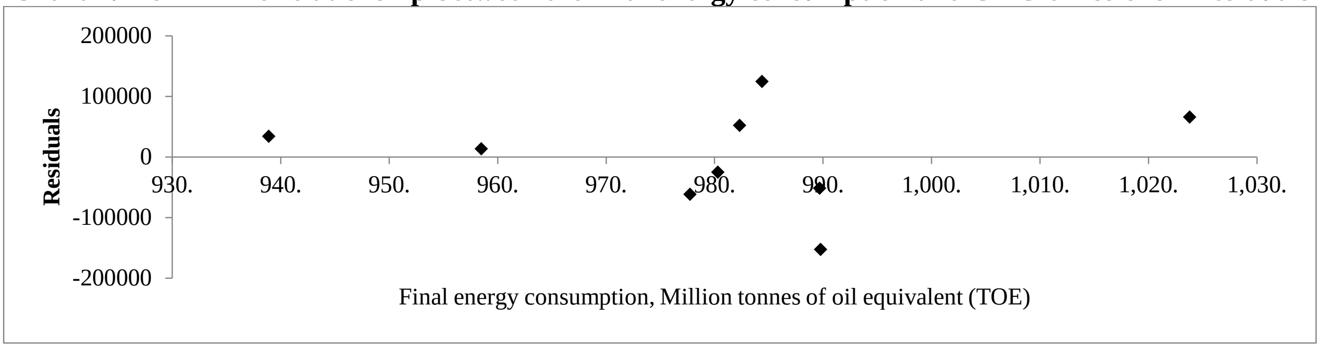
Chart 3: EU27 - The relationship between the final energy consumption and GHG emissions



Source: Author`s representation based on data provided by Eurostat

The residual plot displays a somewhat random pattern that indicates that a linear model provides a decent fit to the data (Chart 4).

Chart 4: EU27 - The relationship between the final energy consumption and GHG emissions - Residuals



Source: Author`s representation based on data provided by Eurostat

The coefficient of determination (r^2) is 0.5829127. That implies that the relationship between the analysed variables explains 58.29% of the variation in the GHG emissions. It does not mean that one variable causes the other.

The linear relationship between the analysed indicators is tested at a 95% level of confidence to see if it is statistically significant.

The null hypothesis (H_0), implies no statistically significant linear relationship in the EU27 between the final energy consumption and GHG emissions.

The alternate hypothesis (Ha) is that there is a statistically significant linear relationship in the EU27 between the final energy consumption and GHG emissions.

$$\begin{cases} H_0: \rho = 0. \\ H_a: \rho \neq 0. \end{cases}$$

While Pearson`s r is the sample correlation coefficient, ρ is the population correlation coefficient.
The ***t-distribution*** is used to test the hypotheses.
Given data:

$$\begin{cases} \text{Level of confidence: LOC=95\%.} \\ \text{Level of significance: } \alpha = 0.05. \end{cases}$$

Number of observations: n=9.
Degree of freedom: Dof=7.

Calculations:

Since there is a two-tailed test, the value of $\frac{\alpha}{2}$ it is calculated, given α = 0.05.

$$\frac{\alpha}{2} = \frac{0.05}{2} = 0.025$$

The goal was to find the value of t that gives the area of 0.025 to the right tail of the t-distribution, namely, $t_{\frac{\alpha}{2}}$ or $t_{0.025}$. T-distribution table was used to find the value of $t_{0.025}$. Taking into consideration the degree of freedom (7) and the level of significance α, the value of $t_{0.025}$ = 2.365 and consequently, since t-distribution is symmetrical, -$t_{0.025}$ = - 2.365 (the value of t that gives the area of 0.025 to the left of t-distribution).

The t-test was calculated using the formula:

$$t = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}} => t = \frac{0.763487}{\sqrt{\frac{1-0.763487^2}{9-2}}} = 3.127788199 \qquad (2)$$

Placing the value of t in the rejection region since the value of t > $t_{\frac{\alpha}{2}}$. Therefore, the null hypothesis (H_0) is rejected. Therefore, there is a statistically significant linear relationship in the EU27 between the final energy consumption and GHG emissions with a 95% level of confidence.

Since the relationship of the variables is statistically significant, it was aimed to finding the equation of the linear regression line, or "the least-squares regression line", which minimises the squares of the distances between the data points and the line (See Chart 1).

To this end, we calculate the regression statistics with Excel (Table 1, Table 2 and Chart 3).

The formula for the least-squares regression line is:

$$y = b_0 + b_1 x \qquad (3)$$

where:

$$b_1 = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}} \text{ (slope)} \qquad (4)$$

$$b_0 = \frac{\sum \boldsymbol{y}}{\boldsymbol{n}} - b_1 \frac{\sum \boldsymbol{x}}{\boldsymbol{n}} \text{ (y - intercept)} \qquad (5)$$

Table 2: Regression Statistics

	Coefficients	Lower 95%	Upper 95%
b_0	-509114.2336	-3627700.315	2609471.847
b_1	4205.748866	1026.180707	7385.317025

Therefore, the equation of the regression line for our sample is: *y = 4205.7x - 509114* as displayed by Excel in Chart 3.

The goal is to find out how much additional y is generated by one additional unit of x. According to the model, for one additional million TOE, the EU27 GHG emissions could increase by 4205.75 thousand tonnes.

The equation of the population regression line is:

$$Y = \beta_0 + \beta_1 x \qquad (6)$$

The confidence interval for the slope (β_1) and y-intercept (β_0) of the population regression line can be constructed based on the data provided by Table 2.

In the case all the population data is known, and a regression line is drawn through it, that the line will have $\beta_0 \in$ [-3627700.315, 2609471.847] and $\beta_1 \in$ [1026.180707, 7385.317025] with a 95% level of confidence.

The same steps were followed for the indicators regarding Romania. The value of r is 0.148435476, meaning that there is no linear relationship between final energy consumption and GHG emissions. The aim was to find out why? Therefore, the percentage of renewable energy sources (PRES) in Romania as compared to the EU27`s was analysed.

Table 3: Percentage of renewable energy sources in the EU27 and Romania between 2010 and 2018,

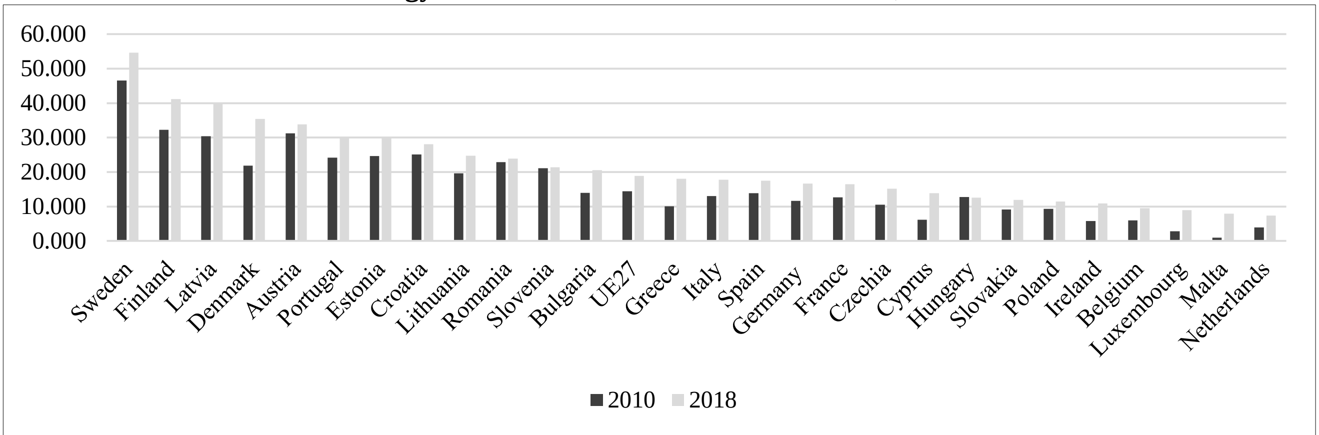
Year	EU27	Romania
2010	14.421	22.834
2011	14.551	21.186
2012	16.024	22.825
2013	16.697	23.886
2014	17.463	24.845
2015	17.841	24.785
2016	18.029	25.032
2017	18.467	24.454
2018	18.909	23.875

Source: Eurostat, 2021d

In all the years of the analysed interval, Romania had a better percentage of renewable energy sources than the EU27 as a whole.

Intuitively, that means the influence of final energy consumption on GHG emissions should be less important in the countries with greener energy production.

Chart 5: Share of energy from renewable sources in the EU27, between 2010 and 2018



Source: Eurostat, 2021c

According to Chart 5, in 2018, Sweden recorded the highest percentage of renewable energy sources (54.65%), followed by Finland (41.16%) and Latvia (40.02%). The last three countries in the ranking were Luxembourg (8.97%), Malta (7.96%) and Netherlands (7.34%).

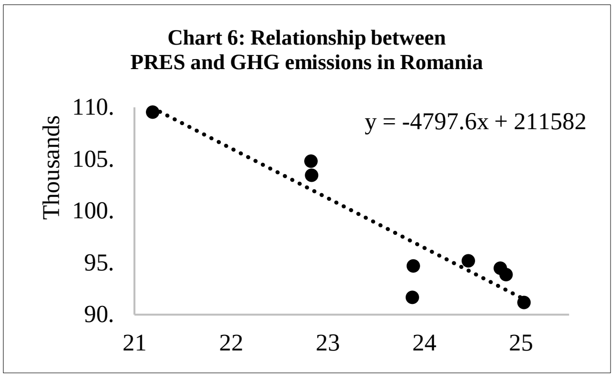
We follow the same procedure to see the correlation strength between the percentage of renewable energy sources and GHG emissions in Romania and the EU27, using the data in tables 1 and 3.

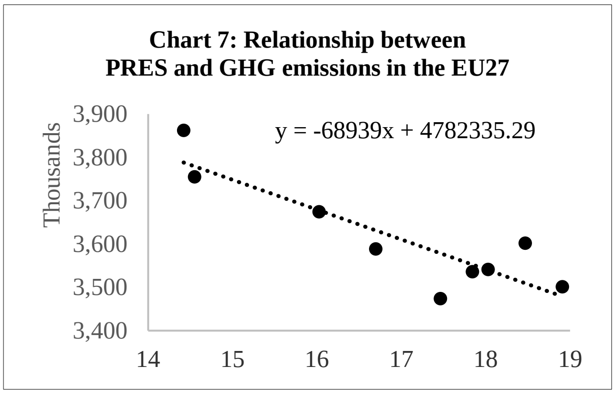
Table 4: T-Distribution indicators for our analysed pairs of variables

	Percentage of renewable energy sources / GHG emissions in the EU27	Percentage of renewable energy sources / GHG emissions in Romania	Percentage of renewable energy sources /Final energy consumption in the EU27	Percentage of renewable energy sources /Final energy consumption in Romania
r	-0.8848	-0.9235	-0.4363	-0.3175
r^2	0.7829	0.8529	0.1903	0.1008

Number of observations (n)	9	9	9	9
Degree of freedom (Dof)	7	7	7	7
$t_{0.025}$	2.365	2.365	2.365	2.365
$-t_{0.025}$	-2.365	-2.365	-2.365	-2.365
Test statistic t	-5.024	-6.371	-1.2827	-0.8860
$t < -t_{0.025}$ or $t > t_{0.025}$	yes	yes	no	no
Statistical significance	(H0) is rejected. There is a statistically significant linear relationship between GHG emissions and the percentage of renewable energy sources in the EU27, with a 95% level of confidence.	(H0) is rejected. There is a statistically significant linear relationship between GHG emissions and the percentage of renewable energy sources in the Romania, with a 95% level of confidence.	(H0) failed to be rejected. There is no statistically significant linear relationship between the percentage of renewable energy sources and final energy consumption in the EU27.	(H0) failed to be rejected. There is no statistically significant linear relationship between the percentage of renewable energy sources and final energy consumption in Romania.

A robust correlation between GHG emissions and the percentage of renewable energy sources in Romania and the EU27 was identified, with negative slopes. Therefore, if the percentage of renewable energy sources increases, the GHG emissions decrease (Charts 6 and 7).





According to the models displayed in charts 6 and 7, for the analysed samples, for one additional percentage point in PRES, the Romanian GHG emissions decrease by 4797.6 thousand tonnes, and the EU27 GHG emissions decrease by 68939 thousand tonnes.

Romania has a higher Pearson coefficient -0,9235, revealing a stronger negative correlation, than in the EU27 (-0,8848). That partially provides an answer to our question. The coefficient of determination (r^2) is also higher in Romania than in the EU27, the relationship between the analysed variables explaining 85.29% of the variation in GHG emissions, in Romania, against 78.29% in the EU27. Therefore, what was intuitively believed, namely that the non-linear relationship between final energy consumption and GHG emissions in Romania compared to the EU27, could be related to the percentage of renewable energy sources in Romania, which is higher than the EU, can be partially supported by statistical evidence. Briefly, energy consumption can even increase without boosting GHG emissions as long as green sources provide that energy.

4 Conclusion

The analysis proves that, in the EU27, there is a strong linear correlation between the final energy consumption and GHG emissions, with a positive slope and a high determination coefficient. We also find that the relationship between the analysed indicators is statistically significant at a high level of confidence. That is not the case for Romania, where the correlation between the two variables is weak and not statistically significant.

This result could be partially explained by the share of renewable energy sources, which is higher in Romania than in the EU and correlates better with GHG emissions, with a negative slope, and is more significant statistically in Romania than in the EU.

Romania ranks 10th in the EU27 regarding the percentage of renewable energy sources, performing better than countries such as Germany, France, Italy and worse than Sweden, Finland, and Austria.

Therefore, decreasing the final energy consumption or increasing the percentage of renewable energy sources could represent an essential driver of the circular economy from the GHG emissions perspective.

Hence, in our opinion, the transition to green energy should be of paramount importance for the transition towards the circular economy, decision-makers and companies being forced by the climate targets to tilt the energy mix in this direction.

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