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Analyzing the Socio-Economic and Energy Implications of Green Economy Transition Across Six EU Member States

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Abstract:

Purpose: *The transition to a green economy is on the European Agenda as a main objective together with climate neutrality whose implementation horizon is 2050. In order to achieve this significant objective, the European Union promotes a regulatory framework based on directives, actions and plans with a view to linking the economy with sustainable development objectives and projects to protect the environment and combat climate change.*
Design/Methodology/Approach: *In this context, we propose to carry out a study on the economic-energy impact of the transition to a green economy by selecting 6 countries according to the criteria for action against climate change and the greenhouse gas emission reduction targets for 2020. The 6 Member States analyzed are Belgium, France, Italy, Germany, Luxembourg and the Netherlands.*
Findings: *The research develops an econometric model of the energy-economic impact of the transition to the green economy based on a methodology that includes econometric modelling of databases using the multiple linear regression method and the use of the GLMM generalized linear mixed model to quantify the transition effort to the green economy in the countries under analysis.*
Practical impliations: *The results of the study will demonstrate the level of impact of renewable energy use on financial development and economic growth and quantify the effects of implementing the transition to the green economy in terms of implementation costs and benefits.*
Orginality: *The conclusions of the study will present the main public policies proposed to foster the transition to a green economy in line with the research results.*

Keywords: *Green transition, sustainable development, renewable energy, responsible consumption, economic impact.*

JEL classification: *Q01, O13, O44.*

Paper type: *Research paper.*

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1. Introduction

The transition to a green economy is a major objective of European policy which aims to eliminate greenhouse gas emissions and achieve climate neutrality by 2050. In this respect, the European Union is pursuing several objectives for the transition to a green economy, namely ensuring ecosystem resilience, improving resource use and improving social equity through targets for limiting greenhouse gas emissions and air and water pollutants.

The mix of measures for the transition to a green economy covers the energy sector, environmental protection, the transport sector, waste management, protection of biodiversity and water sources, promotion of sustainable production and consumption, control of fertiliser use, control of land use.

In the energy sector, the EU has set itself the target of increasing energy efficiency and increasing energy consumption from renewable sources under the 2011 Energy Efficiency Plan (European Commission, 2011), Directive 27/2012(European Parliament, 2012) and the Green Deal climate neutrality agreement (European Commission, 2023).

The European Union's medium and long-term targets are to cut greenhouse gas emissions by 62% by 2030 (European Parliament, 2023) financing innovative technologies and modernisation of the energy sector, phasing out free allowances for industry by 2034 and implementing the EU carbon adjustment mechanism, creating a separate ETS II emissions trading scheme.

All these aspects induce significant adaptation costs for the European economy in view of the transition to the green economy and motivate our scientific approach to assess the energy-economic impact of the transition to the green economy.

Six EU Member States were selected for this study, which had the highest carbon emission reduction targets according to the Effort Sharing Decision reported by the European Environment Agency(European Enviromental Agency, 2023).

The 6 Member States and their carbon reduction targets are: Belgium (-15%), France (-14%), Germany (-14%), Italy (-13%), Luxembourg (-20%), Netherlands (-16%). By pollution level the 6 countries rank in the European top as follows: Germany over 400 million tonnes of CO2 equivalent in 1st place, France over 300 million tonnes of CO2 in 2nd place, Italy over 250 million tonnes of CO2 equivalent in 3rd place, the Netherlands almost 100 million tonnes of CO2 in 6th place, Belgium over 75 million tonnes of CO2 in 7th place and Luxembourg under 10 million tonnes of CO2 in 23rd place.

The specific objectives chosen for the study consist of:

O1: literature review on the energy-economic impact of the transition to the European green economy;
O2: strengthening the evidence base for assessing the main impacts of the green transition;
O3: conceptualisation of an econometric model on the energy-economic impact of the transition to the green economy;
O4: testing, validating and disseminating the results of the model in order to formulate public policies regarding the easier transition to the green economy.

The study continues with the presentation of the specialized literature, methodology, research results, discussions and ends with the presentation of the main conclusions of the research.

2. Literature Review

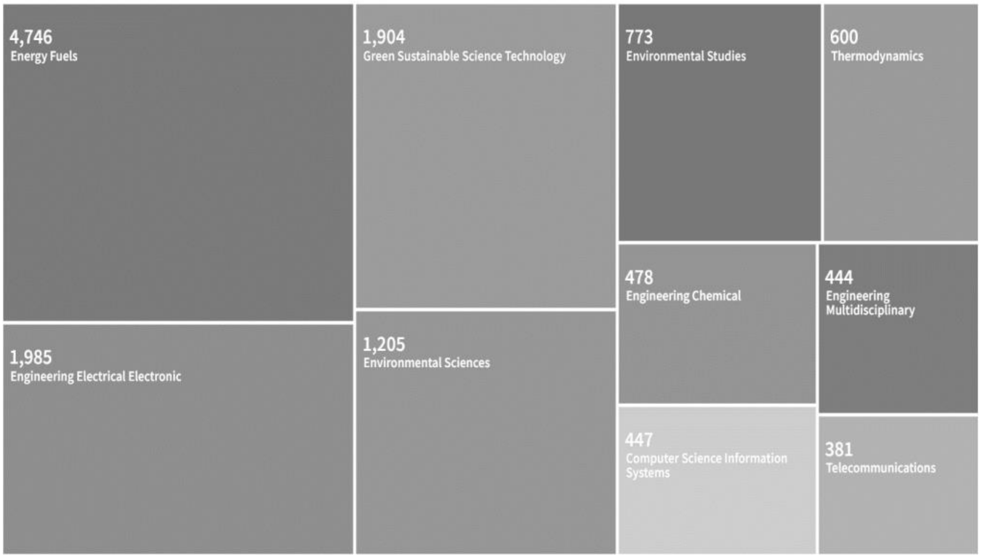
In the literature, the study of the transition to green economy involved the development of a rich research with the publicity reflection of over 30,000 articles, of which 9600 published between 2021-2023, according to the Web of Science database, which was interrogated based on the topic selection algorithm ("renewable energy" AND "Renewable hydropower" OR "renewable energy" AND "Wind" OR "renewable energy" AND "Renewable municipal waste" or "Environmentally related government R&D budget" AND "GDP") (Web of Science, 2023). The 9600 articles were cited in over 30,500 scientific researches excluding self-citations, resulting in 6 citations per item and a calculated Hirsch index of 70 points.

The main research topics that attracted the interest of researchers and a consistent number of citations of over 50 citations per item consisted of: electrocatalytic conversion of carbon dioxide from an energy-economic perspective, presentation of energy storage systems, analysis of smart-city development during IOT, sustainability of renewable energy sources, energy-economic impact study on renewable energy production (solar and wind) in relation to coal consumption, study of integrated energy systems for smart city development, environmental impact of renewable energy systems development, impact of climate change on renewable energy consumption, etc. The main research areas according to the selection made are those in Figure 1.

In extenso, the researchers' concerns have shown through econometric studies that based on the allocation effect, increasing investments in renewable energy can have the effect of increasing carbon dioxide emissions through the multiplier effect (Yang *et al.,* 2022; Pociovalisteanu *et al.,* 2010; Thalassinos and Pociovalisteanu, 2007). Other authors (Frimpong *et al.,* 2023) analysed the energy mix from the perspective of the temporary unavailability of renewable energy sources.

They appreciate that knowing the economic and reliable impact of energy mixes (wind-biomass-battery, solar-wind-biomass or other energy mixes) helps to make optimal investment decisions. Against the background of increasing energy production from renewable sources, some researchers (Ulm, Koduvere and Palu, 2020) appreciates that wind energy can become a dominant source with a low levelised cost.

Figure 1. *Bibliometric analyze report*



Source: *Elaborated by the authors (Web of Science, 2023).*

According to (Ulm, Koduvere and Palu, 2020) the average price of electricity can be reduced by increasing the installed capacity of wind energy, the study being carried out in Estonia and neighbouring countries. From the perspective of climate change and sustainability, other authors (Kim and Hur, 2023) considers it necessary to introduce planning into the energy system as there is a direct link between the performance of renewable energy resources and weather conditions.

This planning must be done by identifying points of overload of energy routes according to seasonal wind power and power demand. Research is useful in developing stable plans for the operation of the integrated energy system. A regression model applied to the economic deflator GDP and greenhouse gas emissions together with the level of investment and the price of wind energy highlighted that the most influential factors on energy models are represented by local energy consumption, local absorption capacity, added value of energy generation, factors influencing renewable energy production parameters.

Some researchers (Ma and Xu, 2021) suggests some policies to increase the absorption capacity of renewable energy in China, the largest producer of renewable energy globally. Other authors (Nazir *et al.*, 2020) considers that energy programmes lead to polarisation of society, creating regional disparities accentuated by environmental impacts and risk factors influencing the energy paradigm. Environmental assessment represents in the opinion of some authors *(McMaster et al.,* 2021) an important point in the development of renewable energy production and supply projects. Differences between environmental assessment systems and procedures according to the authors (McMaster *et al.*, 2021) may have implications for the relative attractiveness of this industry to developers (Thalassinos *et al.*, 2023).

A study conducted on the German market (Keeley *et al.*, 2020) shows that electricity from wind and solar sources has helped to reduce the price of energy quoted on spot markets according to the seasonality of generation, with wind power having the most stable effect. Another study (Hameed *et al.*, 2023) analyzes the possibility of stopping environmental degradation by using renewable hydropower energy.

Research over the period 1975-2020 has shown that switching to hydropower can mitigate environmental losses by adding stability to ecosystems. Other authors (Pandey *et al.*, 2022) takes the view that the role of using renewable energy is also to conserve natural resources. In the opinion of researchers, in the medium term, energy consumption from renewable and non-renewable sources is expected to increase, with the mention that that from renewable sources wind has a faster growth trend.

Analysis of the performance of research and development activities in the field of renewable energy development (solar, wind, biomass, biogas and hydropower) shows that the exploitation of hydropower sources is the most efficient source of energy and that the impact of CDI on wind energy production is maximum (Chachuli *et al.*, 2021).

Innovation is the subject of other research (Mueller and Morton, 2021), the authors show that energy governance is influenced by the costs of research and development.. The authors show that financial means, together with the extensive size (land) and dynamics over time of the sector are the most important factors influencing the social attitude towards the use of renewable resources.

Regional heterogeneity in renewable energy deployment is, in his opinion(Gutierrez-Pedrero, Ruiz-Fuensanta and Tarancon, 2020) related to the factors of investment, knowledge and environment that condition the regional development of industry. In relation to the onset of the new geopolitical conflict, it was noted the usefulness of implementing the strategy for the development of renewable energy (Teng *et al.*, 2022). The authors use stochastic optimization models to reduce the uncertainty of renewable energy generation by proposing a system for operating wind power embedded in reserves that can improve wind power utilization.

The economic potential of the development of renewable energy production is researched by (Zeren and Gursoy, 2022) analysing the relationship between wind energy consumption, economic growth and financial development for 126 OECD member states. According to the results obtained, the use of wind energy has a positive impact on financial development and a negative impact on economic growth. The decelerative component is based on the cost of making the investment for the production of wind renewable energy. The authors show that in order to obtain additional benefits, bureaucratic difficulties should be eliminated, private investments stimulated and social awareness actions of the benefits of using renewable energy should be increased.

3. Research Methodology

In order to determine the economic and energy impact of the transition to the green economy, based on OECD and IRENA information sources, we conducted a panel of data on the electrical capacity, renewable energy generation capacity and the economic-ecological impact of renewable energy use at the level of the 6 selected states, namely Belgium, France, Italy, Germany, Luxembourg and the Netherlands. The analysed indicators are presented in Table 1 below.

Table 1. *Model indicators*

Domain	Description	Symbol	MU	Source
Electricity capacity	Total renewable energy	ECTRE	MW	(IRENA, 2023a)
	Renewable hydropower	ECRHP	MW	(IRENA, 2023a)
	Wind	ECW	MW	(IRENA, 2023a)
	Renewable municipal waste	ECRMW	MW	(IRENA, 2023a)
Electricity generation	Total renewable energy	EGTRE	GWh	(IRENA, 2023b)
	Renewable hydropower	EGRHP	GWh	(IRENA, 2023b)
	Wind	EGW	GWh	(IRENA, 2023b)
	Renewable municipal waste	EGRMW	GWh	(IRENA, 2023b)
Economic environment	Environmentally related government R&D budget	ENVRD	% total government R&D	(OECD, 2023b)
	Climate change mitigation technology patents Tdi	CCTDI	Total number of inventions that seek patent protection	(OECD, 2023b)
	GDP per capita	GDP	US$	(OECD, 2023c)
	Industry GDP (Industry (including construction), value added)	IGDP	% of GDP	(OECD, 2023a)

Source: *Elaborated by authors.*

In order to achieve the objectives of the study, the following working hypotheses were formulated:

H1: The use of renewable energy has a positive impact on financial development and a negative impact on economic growth (based on the cost of making the investment to produce renewable energy). This is supported by research in the literature (Zeren and Gursoy, 2022).

H2: In conditions of sustainable economic growth, the level of spending on environmental protection and combating climate change recovers over time through the direct benefits of stopping the consumption of non-renewable resources. This hypothesis is supported by research in specialized literature (Kim and Hur, 2023).

The proposed econometric model aims to determine the economic and energy impact of the development of renewable energy sources by means of the multiple regression equation for the GDP dependent variable in relation to the indicators presented in Table 1.

After statistical modelling performed in the SPSS version 25 program, the non-standard beta coefficients of the regression variable were obtained, which allowed for the period 2000-2021 the definition of the following model of economic-energy impact (equation 1).

$$\begin{aligned} GDP = & -1.807 * ECTRE + 0.647 * ECRHP + 3.841 * ECW + 15.336 \\ & * ECRMW + 1.207 * EGTRE - 1.155 * EGRHP - 2.029 * EGW \\ & - 8.09 * EGRMW + 923.041 * ENVRD + 13.332 * CCTDI \\ & - 5970.491 * IGDP + 169659.368 \end{aligned} \tag{1}$$

According to the model equation, energy capacity indicators have a significant positive impact on GDP, with the exception of the integrated Total renewable energy indicator (ECTRES).

An interesting aspect shows the inverse correlation between energy capacity and electricity generation when there is a decelerating impact on GDP by increasing renewable energy generation with the exception of the Total renewable energy (EGTRE) indicator. This aspect demonstrates working hypothesis 1.

The regression equation shows that sustainable economic development can be achieved under the conditions of environmental protection and combating climate change. The multiplier effect of the two elements on GDP is 923 dollars for every 1 dollar spent on environmental protection and 13 dollars for every 1 dollar spent on technology patents to combat climate change. This aspect proves working hypothesis 2.

The results of the model show that it is homogeneous, well represented and statistically significant in the sense that the variation of the GDP deflator is influenced from an energy-economic point of view by the variation of independent variables in proportion of 84.3%. The level of error representation tends to 0 according to the GIS coefficient of the function F, which allows the rejection of the null hypothesis and the validation of the alternative hypothesis, according to the data in Table 2.

Table 2. *Model Summary.*

Model [a,b]	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics			Durbin-Watson
					R Square Change	F Change	Sig. F Change	
1	0.925	0.856	0.843	10070.154	0.856	64.981	0.00	1.747
a. Predictors: (Constant), IGDP, ENVRD, ECRHP, EGW, CCTDI, EGRMW, ECTRE, EGRHP, ECRMW, ECW, EGTRE								
b. Dependent Variable: GDP								

Source: *Authors' calculations.*

The application of the ANOVA test showed that the regression component is 6 times better represented than the residual component in the sum of function squares, which confirms the high significance level of the model. The value of the function F is calculated at 64,981 points and the margin of error representation is lower than the chosen representation threshold, $\alpha < 0.05$ according to the data in Table 3.

Table 3. *ANOVA test*

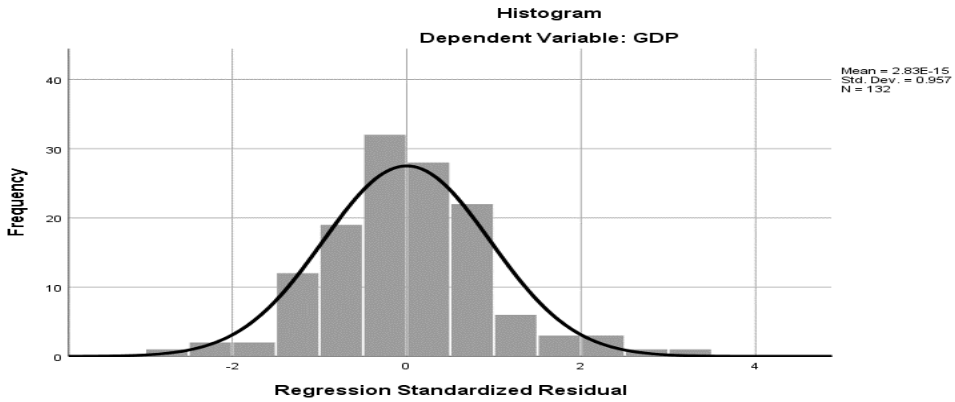
Model[a,b]		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	72485671007.752	11	6589606455.250	64.981	0.000
	Residual	12168961315.240	120	101408010.960		
	Total	84654632322.992	131			
a. Dependent Variable: GDP						
b. Predictors: (Constant), IGDP, ENVRD, ECRHP, EGW, CCTDI, EGRMW, ECTRE, EGRHP, ECRMW, ECW, EGTRE						

Source: *Authors' calculations*

The histogram distribution of the dependent variable shows a high homogeneity of the data, the mean being calculated at 2.8% distribution from the median for a number of 132 observations with accumulation below the Gaussian Curve and an acceleration of accumulation towards the median range on the upward slope of the curve as shown in Figure 2.

As a result, the proposed model for assessing the economic and energy impact of the use of renewable energies (hydroelectric, wind and renewable urban waste) is valid and representative, constituting a viable energy mix from the perspective of transition to green economy.

Figure 2. *Model histogram*



Source: *Elaborated by authors.*

4. Research Results and Discussion

In order to identify the regional economic and energy impact, descriptive statistics from Table 4 below have been developed.

Table 4. *Descriptive statistics*

Indicator	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Be	Fr	De	It	Lu	Nl
ECTRE	3,625.00	33,254.50	61,983.00	35,165.50	132.50	3,112.50						
ECRHP	110.00	23,720.50	5,359.00	17,671.50	34.00	37.00						
ECW	990.50	6,335.00	27,807.50	6,356.00	44.50	2,276.50						
ECRMW	116.00	410.50	732.00	364.50	9.00	309.00						
EGTRE	7,482.50	77,967.50	114,609.00	79,974.00	275.00	11,422.50						
EGRHP	317.50	59,249.50	20,090.50	44,868.00	105.00	99.00						
EGW	1,802.00	11,158.50	45,621.50	9,491.00	64.00	4,781.50						
EGRMW	693.50	2,023.00	4,751.00	2,105.00	31.00	1,833.50						
ENVRD	2.00	2.00	3.00	3.00	3.00	1.00						
CCTDI	19.50	503.50	1,856.00	192.00	3.00	77.50						
GDP	44,276.00	40,566.00	41,843.00	34,011.00	105,491.50	50,511.50						
IGDP	21.00	18.00	27.00	22.00	12.00	20.00						

Source: *Authors' calculations.*

Table 4 shows that the strongest economy with a stable economic-energy balance is Germany, which according to data from the European Environment Agency (European Enviromental Agency, 2023) ranks first in greenhouse gas emissions with the highest allocations to environmental protection and research and development of climate change technologies. In terms of the second-largest economy, France excels in the use of water resources and is the second most carbon-intensive economy.

Luxembourg ranks third in terms of economic-energy mix, with high economic growth and a maximum GDP deflator (2.5 times higher than Germany). The main characteristic of this country is represented by the small number of inhabitants, which gives it an advantage related to carbon emissions (twenty-third place at EU 27 level). The last two positions in the regional ranking are occupied by the Netherlands and Belgium.

We analyzed regional results in terms of a model based on the Forward Stepwise method, quantifying the effects of the model in Summary Table 5.

Table 5. *Model Forward Stepwise Summery.*

STEP		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Information Criterion		3,576.529	3,535.347	3,471.196	3,470.148	3,454.808	3,452.373	3,451.593
Effect	IGDP-transformed	✓	✓	✓	✓	✓	✓	✓
	ECRHP-transformed		✓	✓	✓	✓	✓	✓
	CCTDI-transformed			✓	✓	✓	✓	✓
	EGTRE-transformed				✓	✓	✓	✓
	EGW-transformed					✓	✓	✓
	ECW-transformed						✓	✓
	ECRMW-transformed							✓

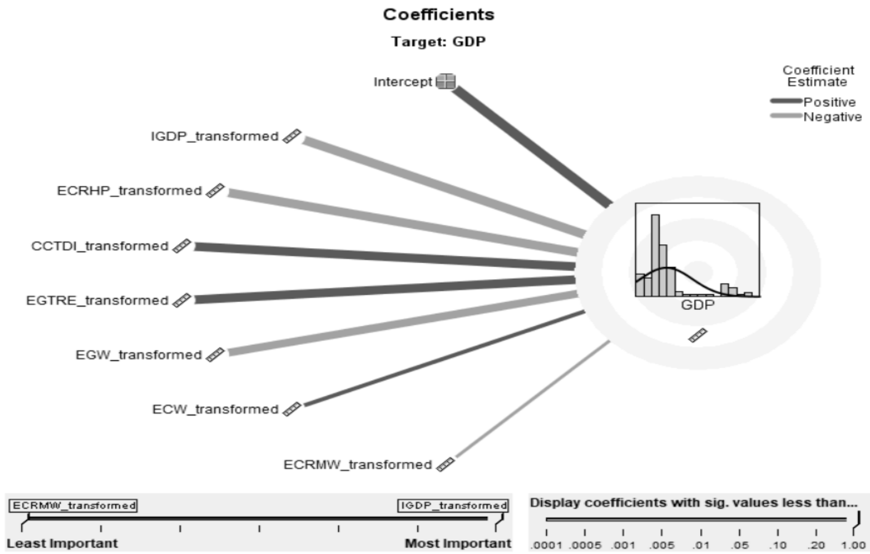
Source: *Authors' calculations.*

Table 5 shows that the maximum effect on GDP is generated by economic and innovative components, followed by elements regarding hydrographic energy capacity, total renewable energy generating capacity, the weakest effect being registered in the field of municipal renewable resources.

Thus, implementation costs demonstrate the reduction of economic development by up to 3.5% of GDP based on the transition effort to the green economy. These effects are shown schematically in Figure 3.

The proposed model was found to be able to economically quantify the costs of the transition to the green economy estimated at 3.5% of GDP based on the GLMM generalized linear mixed model whose output shows that as the level of economic development increases, the impact of green transition and environmental protection expenditures increases in magnitude based on the estimated averages of the significant fixed effects in Figure 3.

Figure 3. *Estimated diagram of the intensity of influence of regression variables on GDP.*



Source: *Elaborated by authors.*

5. Conclusions, Proposals, Recommendations

The last part concludes the results of the study and the limitations related to the methodology used, availability of data, as well as recommendations and comments for future research. It includes the main research findings. Conclusions are only original contribution of the paper to the field of study. It indicates the value of research and the material presented. It should be a strong recapitulation of major ideas of the paper.

The study achieved its specific objectives by conducting a critical literature review on the basis of which the working hypotheses were defined. These have been validated following the implementation of the model on the assessment of the economic-energy impact of the use of renewable energy at the level of the 6 Member States of the European Union, namely Belgium, France, Italy, Germany, Luxembourg and the Netherlands.

The results of the model show that: the use of renewable energy has a positive impact on financial development and a negative impact on economic growth (based on the cost of making the investment to produce renewable energy); In conditions of sustainable economic growth, the level of spending on environmental protection and combating climate change recovers over time through the direct benefits of stopping the consumption of non-renewable resources.

The proposed model quantified the green transition effort at 3.5% of GDP based on estimated averages of significant fixed effects. The results of the model have a reapplicable character generated by the extended methodology and the significant period analyzed, the model presenting a high degree of statistical significance and an optimal level of homogeneity of data.

The main public policies that can be implemented to facilitate the transition to the green economy are related to: favouring investment in renewable energy infrastructure; intensifying the innovation research process in the field; setting up central European bodies to monitor the implementation of renewable energy production; promoting public policies to make energy consumption responsible; granting incentives for renewable energy producers.

The main limits of the study are the small number of indicators and the small number of countries on which the research was carried out, the authors proposing on the next occasion to extend the research to EU 27 level and to complete the database with other relevant indicators to improve the results of the model.

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