SUSTAINABLE ENERGY FOR SUPPORTING THE SUSTAINABLE DEVELOPMENT: EMPIRICAL APPROACH FOR ROMANIA

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ABSTRACT: Low-carbon economy transition is a priority objective of the European Union's actual strategy of sustainable development, which aims to detach economical activities from the negative consequences produced on the environment. For a country, the requirements imposed by accomplishing sustainable economical growth in terms of energy safety involve drawing a new architecture of the energy systems. This paper is not about highlighting the characteristics of the Romanian energy sector, but aims to point out its capacity to contribute to reducing the impact on the environment. The study covers the period 1990 – 2012 and follows the EU members, amongst which a special attention is given to Romania. The main findings of the paper highlight the significant factors of energy sustainability and the impact of consuming various energy sources on atmospheric emissions, at European level. In Romania's case, a positive relation is identified between economical growth, consumption of energy from non-renewable sources and gas emissions, whereas increasing energetic efficiency and using energy which comes from renewable sources are reducing air pollution. For increasing the sustainability character of the Romanian economy, this study recommends changes in the energy mix, especially stimulating the investments in renewable energy sources.

Keywords: energy sustainability, energetic efficiency, greenhouse gases, renewable energy sustainable development

Jel Codes: O44, Q01, Q42

Introduction

The integrated approach of human activities' impact on ecosystems and environment has found, in the last years, a complex expression in the Club of Rome's research program, presented as a sequel of the Limit to Growth Report (1972). The program foresees a New Path to World Development and requires urgent actions on the following directions: environment and resources, globalisation and finance, international development, in order to have, in the future, a more resilient and sustainable planet (http://clubofrome.org). The specialists alert that the absorption capacity of greenhouse gas emissions by the natural capital is already exceeded twice and major changes are required to ensure survival, the only valid option being development in a sustainable way (Randers, 2012).

Problems regarding environment pollution, consumption and management of energy resources are the point of debates in the World Economic Forum, leading to the construction of a Global Energy Architecture, for which each country must bring a significant contribution. These concerns line up with the fulfilling of sustainable development requirements, namely the transition towards new energy models capable of ensuring concomitant economic growth, environmental sustainability and energy security for all. (WEF, 2013)

For the European Union, one of the headline targets of the Europe 2020 strategy to a smart, sustainable and inclusive growth economy aims the area of climate change and energy. It

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focuses on decoupling of economic growth from the use of resources, and must be transposed at national level by all of the EU members. The goals pursued are the accomplishment in Europe of more resource efficient economies, which have also, be greener and more competitive. The recommendations include promotion of low-carbon industries, decreasing greenhouse gas emissions with at least 20% compared to 1990 and also increasing the use of renewable energy resources and of energetically efficiency with minimum 20% compared with the levels registered in 1990. (European Commission, 2010)

At European Union level the main component of greenhouse gas emissions also responsible for the climate change is the carbon dioxide (CO2). In 2010, this had a share of 82.4% in total GHG emissions on EU territory, the others gases having a lower contribution: methane: 8.6%, nitrous oxide 7.2% and hydrofluorocarbons 1.8% (EEA, 2012).

According to the data provided by The European Environmental Agency, in 2011, EU-15 own o share of 79.8% in total EU-27 GHG, the most important polluter being Germany (20.1%). Amongst the central and east European countries, the biggest share in greenhouse gas emissions is owned by Poland, with a contribution of 8.8% in total GHG. Compared with the reference level of the year 1990, in the entire European Union, the polluting emissions decreased with 15.4%, the decrease being 10.6% for the developed countries in EU-15 (EEA, 2012).

As a signatory country of the Kyoto Protocol, Romania assumed its obligations according to the treaty and is making constant efforts to address the problems regarding the climate changes and the increase of its economic sustainability. Under Kyoto Protocol recommendations, in the period 1990-2011, Romania decreased its polluting emissions with 49.5%, registering one of the highest rates in Europe (figure 1).

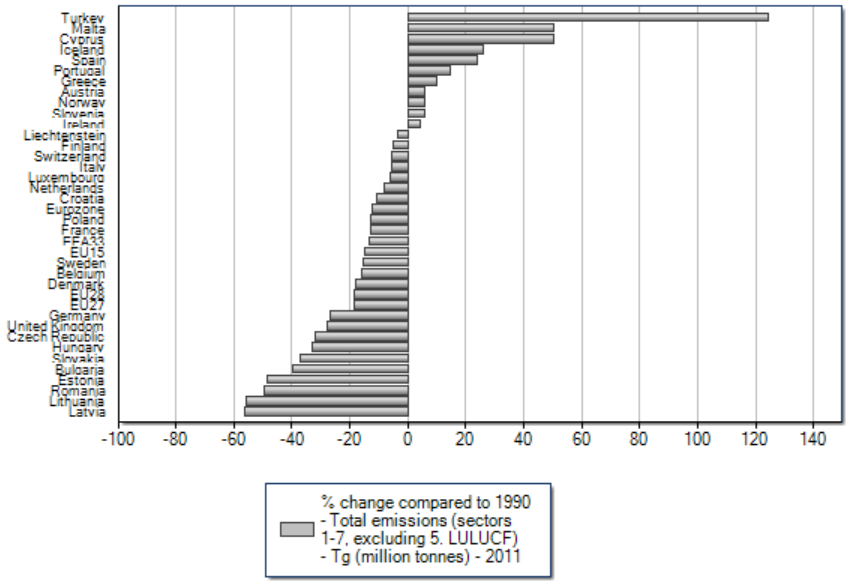

Figure 1. Change in GHG (CO2 equivalent) emissions by country (%), 1990-2011 (Source: EEA database)

At this moment (2011), Romania has a contribution to the atmospheric emissions of the European Union of 123.3 million tones CO2-equivalent, which represents a share of 2.7% in total GHG emissions.

Looking at the modifications occurred in the gas emissions by economical sectors, one can observe that significant decreases were registered in most areas (between -76.8% and -30.7%). Increases of CO2 level were registered in transportation and waste processing (figure 2).

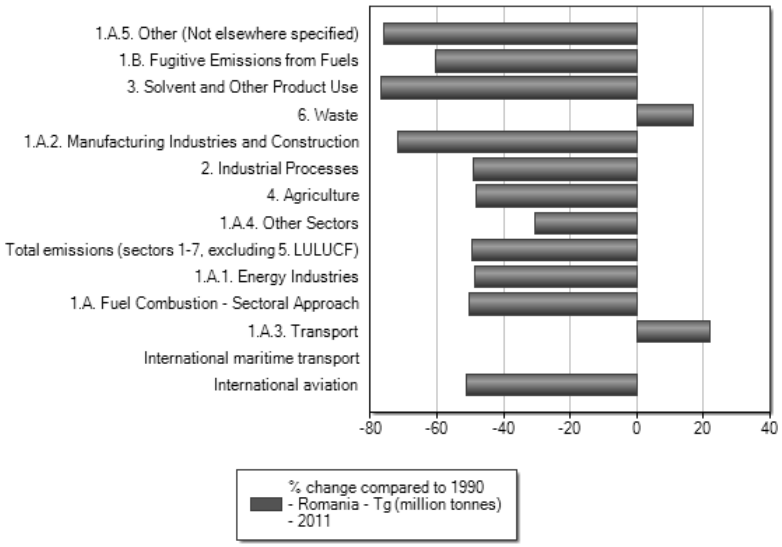

Figure 2. Change in emissions by sector (%) 1990-2011
(Source: EEA database)

The energetically strategy of Romania for the period 2007-2020 provides as strategic objective for the energy sector: the energy safety, sustainable development and competitiveness (RES, 2007).

Literature review

The current study makes an evaluation of the trends occurred in the Romanian energy sector starting with the year 1990 and analyses the sustainability of the economical activities approached especially through the consumed energy point of view. The action of the significant factors identified is compared with the average levels registered by the EU group of countries. The study brings its own contribution by identifying the most important factors which explain the evolution of gas emissions in Romania throughout the last two decades and by quantifying their action, which constitutes a ground base to appraise the level of sustainability of Romanian energy model. The results obtained allow the formulation of some directions for sector policy improvement and for energy resources management.

The pressure applied by the economical activities on the environment is carefully monitored at European Union level and constitutes the object of climate and energy strategy across the territory of the region (European Commission, 2010; EEA, 2012). The environment pollution problem is also the point of scientific debates as an integrated part of the concerns for harmonization of the ecosystems, economic systems and social systems, according to the sustainable development principle.

In the specialized literature there are various studies for European countries regarding the efficiency of renewable and non-renewable energy sources consumption, determined by using the Data Envelopment Analysis method. The considered output variable is the Gross Domestic Product and the technical efficiency indexes resulted determine a relationship between the macroeconomic results and the consumption of energy resources and other production inputs (Chien and Hu, 2007; Halkos and Tzeremes, 2013). Other authors determine the technical efficiency indexes relative to environmental pollution, energy consumption and economic activity, considering besides the desirable effects retrieved in the GDP also the undesirable effects such as the CO2 emissions (Bampatson and Hadjiconstantinou, 2009).

Various recent studies are researching the connection between the energy sources and the economical growth and sustainability by using econometrical modelling techniques or the Granger causality tests. The energy sustainability is considered to be derived from the use of renewable energy, which contributes to the increase of energetically efficiency and the decrease of pollution (Silva et al., 2012; Romanao and Scandurra, 2011). In other studies, a connection is identified, formed between the GDP and the renewable energy consumption, by generating capital (Chien and Hu, 2008) or based on the increase of price for the renewable energy (Chang et al., 2009). A causality relationship, in which GDP and atmospheric emissions have a significant impact on renewable resources consumption, is studied by Sadorsky (2009), for the highly developed countries.

Some authors analyse the causality relationship between the economical growth and energy consumption by emphasizing the role of nuclear energy as a viable important source for ensuring a country's energetically independency and for diminishing the atmospheric pollution and the greenhouse gas emissions (Apergis and Payne, 2010; Wolde-Rufael, 2012; Iwata et al., 2010). Another renewable source of energy with impact on sustainable development is the hydropower energy (Yuksel, 2010).

An important part of the specialized literature focuses on investigating the relationship between carbon emissions and the determinant elements. A description of the relationship between the polluting emissions, energy consumption, foreign trade and economical growth can be found in the study of Halicioglu (Halicioglu, 2008). The results of some recent studies show that there is a causality relationship, both on long and short term, between economical growth, energy consumption and carbon emissions (Iwata et al., 2010; Nazir and Rehman, 2011; Apergis and Payne, 2010; Atici, 2009). Similar results were identified also for Romania (Shahbaz et al. 2012).

A complex methodology of analyzing the factors which determine greenhouse gas emissions is presented in the 2012 European Environmental Agency annual report. This consists in decomposition analysis and regression analysis. The explanatory variables of CO2 evolutions are socio-economical and environmental factors, such as population, GDP, energy resources consumption, energy intensity (EEA, 2012).

Structural changes of the Romanian energy sector

In the ranking performed by the World Economic Forum, relative to the EAPI 2014 (Energy Architecture Performance Index), Romania ranks the 12th (with a score of 0.66/1), out of 124 countries. In this hierarchy, amongst the Eastern European group of countries, it is only surpassed by Latvia, which ranks the 10th. EAPI measures the efficiency of energetic systems and includes many indicators, grouped in three parts, each allowing the evaluation on an important direction of sustainable development: economic growth and development, environmental sustainability, energy access and security. Romania has an EAPI Index higher than the total level of EU (0.62/1), which shows its higher contribution to decrease of atmospheric pollution in the region and to increase of energetic security. Also, the high ranking shows that, together with the other European countries, Romania is engaged in the transition to a low-carbon economy as set out by the European Union's 2020 Strategy.

The characteristics of the energy system in Romania and the trends shown in the last two decades (since Kyoto Protocol) are illustrated in Table no. 1.

Table no. 1

Energy System in Romania, 1990-2011

Indicators	UM	1990	2011	2011/1990 (%)
Electricity production	mil.kWh	64309	61999	-3.6
Electricity production from coal sources	mil.kWh	18502	24803	34.1
	% of total	28.8	40.0	-
Electricity production from natural gas sources	mil.kWh	22573	8365	-62.9
	% of total	35.1	13.5	-
Electricity production from oil sources	mil.kWh	11823	769	-93.5
	% of total	18.4	1.2	-
Electricity production from non-renewable sources (coal, oil and gas)	mil.kWh	52898	33937	-35.8
	% of total	82.3	54.7	-
Electricity production from nuclear sources	mil.kWh	-	11747	
	% of total	-	18.9	
Electricity production from hydroelectric sources	mil.kWh	11411	14728	29.1
	% of total	17.7	23.8	-
Energy use	kg of oil equivalent per $1,000 GDP (constant 2005 PPP)	341.7	151.4	-55.9
Fossil fuel energy consumption (coal, oil, gas)	% of total	96.1	77.7	-19.1
Alternative and nuclear energy use	% of total	1.6	12.5	681.2
CO2 intensity	kg per kg oil equivalent energy use	2.6	2.2	-15.4
CO2 emission	metric tons per capita	8.7	5.9	-32.2

Source: World Development Indicators, http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators

The energy sector of a country is most responsible for the climate change and for the contribution to environment pollution. In Romania, important changes have been made, both in the structure of energy production and in the structure of consumption, the trends following the line of the transformations required by de environment strategy of the European Union. In 2011, the energy production from oil, coal and gases which largely contributes to GHG emissions was lower with 35.8% compared with 1990, the most significant decrease being registered by electricity production from oil sources (-93.5%) and electricity production from natural gas sources (-62.9%).

In this period, the commissioning of the nuclear plant in Cernavoda took place (1996) and hydropower groups have been rehabilitated, which lead to an increase of energy production from non-polluting sources with 42.7%. At this moment, Romania has a diversified energy structure, in which the electricity produced by non-renewable energy sources is completed with the one obtained from nuclear and hydroelectric sources. It model of energy consumption is less and less polluting, the carbon emissions intensity decreasing with 15.4% in the last two decades.

Although, compared with 1990 the energy consumption from fossil fuels dropped with 19.1%, it still represents 77.7% from the total energy consumption in the country, which means that this is the direction to be followed in order to reduce pollution.

A notable element which indicates the qualitative transformation of the energy system is the decrease of consumption per value unit, which means an increase in efficiency. De decrease of energetically intensity is illustrated by the Energy Use indicator, decreased with 55.9% compared with the year 1990. This trend is explained by the actions of economic restructuring made after 1990, by internal energy market liberalization, by diminishing consumption of electricity through improving production and energy consumption technologies, by upgrading the transportation and distribution network (RES, 2007).

Methodology

This study's objectives are to identify the elements related to energy system, which have an impact on atmospheric emissions, the analysis of the relationship between the energy emissions and various significant factors in the sustainable development system and the characterization of the Romania's energy system sustainability. For fulfilling these tasks, the starting point was the theoretical and practical approaches reported in the literature and the multifactor regression analysis for a panel dataset was used. The information used for analysis is provided by the World Bank database in the period 1990 – 2012 for the EU members. Cyprus and Malta were excluded from this analysis, due to incomplete sets of data.

At the entire European Union level, a headline indicator for monitoring the atmospheric pollution is the carbon dioxide emissions, the largest GHG gases. This indicator is an unwanted effect which accompanies the economic growth, and in analysis has been considered an endogenous variable. The energy emissions are proxied by the CO2 emissions and the form of manifestation is influenced by various factors.

The indicators required to evaluate the sustainability of the energy systems were established based on approaches in the specialized literature and especially on the methodological guiding of EEA. These express the environmental impact of several socio-economic components or of certain characteristics of the energy system and represent the explanatory variables of the studied phenomenon.

In order to identify the impact of economic activity on carbon dioxide emissions the indicator Gross Domestic Product per capita was used, which is a synthetic indicator measuring a country's total output and also indicating the economy's development level and standard of living. It is expected that the increase of GDP to be accompanied by the increase of atmospheric pollution, in case the rhythm of economical growth is not surpassed by the rhythm of environmental technologies implementation (Atici, 2009).

In current paper, the characteristics of the energy systems are highlighted by the energy efficiency and energy sources mix, and the explanatory variables are: energy intensity, expressed by the indicator Energy Use (kg of oil equivalent) per 1000$ GDP, indicator which is considered a primary instrument in reducing the environmental impact by decreasing the fossil fuel consumption (Sioshansi, 2013) and which indicates the economy's energy efficiency; Fossil fuel energy consumption (% of total), which represents the energy consumption from non-renewable sources (coal, oil and gas); Alternative and nuclear energy (% of total energy use), which shows the energy consumption of non-polluting sources. It is expected that the above mentioned factors should exert a direct action on CO2 emissions, except for the consumption of energy form alternative and nuclear sources, which should generate a decrease in atmospheric pollution (Romano and Scandurra, 2011). The static characterization of the variables is represented in the Table no. 2.

Table 2

Descriptive statistics of variables related to energy sustainability

Variables	Mean		Maximum		Minimum		St.Deviation	
	EU	**RO**	**EU**	**RO**	**EU**	**RO**	**EU**	**RO**
Dependent variable: CO2 emissions, metric tons per capita	8.41	4.78	27.42	6.85 (1990)	2.63	3.67 (2010)	3.80	0.79
Explanatory variables:								
GDP per capita growth, annual %	2.04	1.57	13.02	8.69 (2004)	-31.18	-12.14 (1991)	4.37	6.03
Energy use (kg of oil equivalent) per $1000 GDP (constant 2005 P	177.10	236.62	473.97	341.69 (1990)	84.37	149.35 (2009)	69.85	61.78
Fossil fuel energy consumption, % of total	78.13	86.61	98.53	96.15 (1990)	31.98	75.07 (2010)	15.00	6.22
Alternative and nuclear energy, % of total energy use	13.87	6.82	52.26	13.67 (2010)	0.003	1.58 (1990)	13.21	3.6

Source: World Development Indicators, http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators

The items taken into account for the analysis of the energy systems sustainability register significant variations, in time, from country to country. Significant differences are identified for the energy intensity indicator, for which the standard deviation is of 69.85 kg of oil equivalent per 1000$ GDP and for the share of fossil fuel energy consumption and for alternative and nuclear energy in total energy use, for which variations of 15.0% and 13.21% were registered.

The comparative analysis of the variables related to energy shows that, for some of the variables, the level of indicators registered in Romania are significantly different compared with the average registered by the EU group of countries (the share of alternative and nuclear energy in total consumption is two times lower). A favourable situation is registered by the pollution emissions, which in Romania are 1.8 times lower than in the rest of the Eastern European countries. The maximum level of emissions in EU was of 27.42 tons per capita, while in Romania the maximum level was of 6.85 tons per capita (1990).

The variables presented are used to identify the determinant factors of energy emissions on the territory of the new member states of EU, including Romania, based on regressional modelling. Taking into account the peculiarities of the countries examined, the collected data were organized as a panel dataset. The general form of the estimated model is as it follows:

$$CO2KG_{it} = a_i + b_1(GDPKG_{it}) + b2(DEUGDP_{it}) + b_3(ShFEG_{it}) + b_4(ShAEG_{it}) + \varepsilon_{it} \quad (1)$$

in which: a is the intercept, b_1, b_2, b_3, b_4, b_5 are the regression coefficients of the independent variables, $CO2KG_{it}$ is the annual growth rate of CO2 emissions per capita (%), $GDPKG_{it}$ is the annual growth rate of GDP per capita (%), $DEUGDP_{it}$ is the absolute change of Energy use per GDP (kg of oil equivalent per $1000 PPP), $ShFEG_{it}$ is the annual growth rate of

share of Fossil fuel energy consumption of total energy (%), $ShAEG_{it}$ is the annual growth rate of share of Alternative and nuclear energy of total energy (%), ε_{it} is the error term, *i* represents the country (i=1,…N) and *t* is the year of data collection (t=1,…T). Based on theoretical and empirical observations we expect that sign of b_1, b_2, and b_3 to be positive and sign of b_4 to be negative.

The parameters of the model are estimated using the Generalized Least Squared (GLS) regression-based framework with fixed effect, in order to catch the particular action of certain influence factors in every country.

Testing the unit root of variables (ADF test) emphasized the fact that some of these variables are not stationary and have I(1). That is why the model integrates short-term dynamics of variables (annual growth rates or absolute changes) and introduces a first order autoregressive AR term for preventing residual autocorrelation. A second unit root test applied to time series highlights that the presented variables with annual growth rates and absolute stations become stationary. In order to obtain estimators robust to contemporaneous correlation and heteroskedasticity, the White cross-section method is used. The estimators resulted represent elasticity coefficients which show the change in CO2 gases from a unit increase in independent variables.

Results and discussion

The estimation of the relationship between energy emissions proxied by CO2 gases and its determinants was performed with the speficiation from the Equation no. 1. Two models were obtained, explaining this relationship both for the analyzed group of countries and for Romania. Model no. 1 allows the analysis of environmental efficiency and energy consumption from non-polluting sources (alternative and nuclear sources) and model no. 2 express the environmental impact made by energy consumption of fossil fuels (table no. 3).

Table 3

Estimators of energy emissions, EU' countries and Romania 1990-2012

Model 1	dependent variable: **CO2KG**	**GDPKG**	**ShAEG**	**DEUGDP**
	EU R2 adj.=0.727 F-stat=43.4 (0.000)	0.915 (0.0000)	-0.076 (0.0000)	0.486 (0.0000)
	RO R2 adj.=0.870 F-stat=30.6 (0.000)	0.974 (0.0000)	-0.069 (0.0913)*	0.322 (0.0000)
Model 2	dependent variable: **CO2KG**	**GDPKG**	**ShFEG**	**DEUGDP**
	EU R2 adj.=0.846 F-stat=88.9 (0.000)	0.846 (0.0000)	1.232 (0.0000)	0.450 (0.0000)
	RO R2 adj.=0.910 F-stat=46.0 (0.000)	0.926 (0.0000)	1.171 (0.0000)	0.331 (0.0000)

Source: authors' calculation; p-values in parentheses;
* 10% level of significance

The accuracy and specification quality of the regressions models obtained was evaluated using an F-test to control the overall significance and t-test for variables. The quality of the residual components (error terms) was tested for pointing out the normality of errors, autocorrelation (AC values), serial correlation (Breusch-Godfrey LM test) and heteroskedasticity

(Breusch-Pagan-Godfrey test). The results of the tests indicate the validity of the models with significant coefficient for a 5% level.

The analysis of the resulted data shows that at EU states level, the most important contribution to the creation of polluting emission is brought by the energy consumption from non-renewable sources. The increase of it with an annual rhythm of 1% causes an annual change of CO2 gases per capita of 1.23%. Also, the polluting emissions increase with around 0.9% annually, in case of the growth of GDP rhythm per capita with 1% and with 0.5% in case of increase of energy intensity with 1kg of oil equivalent per $1000 GDP (the energy efficiency drops). The 1% annual change of the share of alternative energy sources consumption produces a decrease of the rhythm of polluting emissions growth of 0.08%.

For Romania, the interpretation of the estimators obtained as elasticity coefficients reveals several aspects which characterize the sustainability of the energy system and the measure in which the economical development acquired traits of sustainable development.

In Romania, the elasticity of atmospheric emissions related to GDP is below 1, but high enough (0.92-0.97), which shows that the rhythm of economical growth is generating a significant impact on polluting emissions modification. The elasticity of CO2 emissions to the indicator which quantify the energy intensity (DEUGDP) is of 0.3 and lower than in EU, which seems to indicate the important progresses made by Romania in the direction of innovation, of less polluting technologies and with less energy consumption. The factor with the highest influence on the polluting emissions is the fossil fuel energy consumption, for which the elasticity is over 1 (1,17), but slightly lower than in EU. A factor which contributes to the decrease of CO2 emissions is the consumption of energy from alternative and nuclear sources (-0.07; probability 90%).

The results obtained for Romania are in accordance with Shahbaz et al. (2012), which run an analysis of the relationship between economical growth, energy consumption and carbon emission in Romania, for the period 1980-2010. Their study ascertains that the energy consumption has the highest contribution in GDP growth, a lower influence being exerted by economical growth. The findings also agree with the conclusions of other studies on the causes of environment degradation in developed and developing countries (Stern, 2004). Based on them, may be specified as appropriate also in Romania's case several directions of action, in order to accelerate the trend of decreasing pollution: decreasing energy intensity by increasing productivity, so that each input would produce more output, acceleration of technological changes, in order to reduce emissions, so that a unit of input would generate less emissions, which requires intensification of innovation, shifts in fuel composition and favours renewable sources. Changing the energy mix and a faster growth of consumption from alternative sources, compared with fossil fuel energy consumption represent, in perspective, on important way of improving sustainability in energy sector and also a stimulation of economic growth in a sustainable system.

Conclusions

The analysis performed in this study intended to provide additional information concerning environmental efficiency of the energy sector in Romania and the EU states since 1990. The models identified in Romania characterize the sustainability of its economic growth and identify the determinants of polluting emissions, related to energy system. The two important actions for Romania, namely the signing of the Kyoto Protocol and joining the European Union, directed the efforts of the decision makers to legislation changes regarding environment protection, to creation of specialized institutional structures, to elaboration of national environment strategies, followed by initiation of technology restructuring measures for reducing environment impact. As a result, the intensity of energetic emissions decreased and

favourable changes occurred in the structure of production and consumption of energy, which lead to an important reduction of carbon emissions per capita.

The results of regression analysis performed from the sustainable development point of view reveal that a powerful impact on polluting emissions, in a direct way, is applied by the size of fossil fuel energy consumption and the rhythm of economical growth. The energy intensity is an influence factor compared with which the elasticity of the polluting emissions is lower than the European average, this demonstrating the favourable structural changes occurred in the economy, in order to reduce climate changes. In the analyzed relationship, the only elasticity coefficient with a negative expression belongs to the variable Alternative and nuclear energy as share in total energy use, which shows that this factor has a determining influence on the decrease of polluting emissions and on the increase of energy sustainability, this aspect being consistent with Silva et al. (2012).

In order to continue the growth of environmental efficiency of the energy system and also to strengthen sustainable development, the energy policies have to focus mainly on encouraging investments in technological innovation, on stimulating the introduction into production of environmental friendly technologies and on development of research and investment in renewable energy and in the general increase of productivity, in order to reduce energy intensity.

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