The impact of circular economy indicators on the gross inland consumption of the energy of the European Union

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Abstract: - The development of the economy and society is strongly influenced by the intensive use of available natural resources that directly affect the environment. The European Commission envisages a transition from the current economy, characterized by linearity, in the direction of a circular economy. To assess the impact of the circular economy on the growth dynamics of the European Union economy, it is necessary to choose indicators. The European Union decided to use indicators of a circular economy, divided into the following four thematic areas: production and consumption, waste management, secondary raw materials; competitiveness and innovation. The transition to a circular economy affects EU industry performance. In this regard, in this article we consider the impact of the indicators of the circular economy on the gross domestic energy consumption of the European Union. In this study, we estimate the effect of circular economy indicators on gross domestic energy consumption. The purpose of these studies was to identify indicators of the circular economy, which have the greatest impact on the gross domestic energy consumption of the European Union. The study was conducted using the Statgraphics Centurion software package. The initial data for the study were data from the official Eurostat website for the period from 2007 to 2016. As a dependent indicator was taken gross inland consumption of the energy, factor signs were generation of municipal waste per capita, domestic material consumption per capita, resource productivity, recycling of biowaste, recycling rate of packaging waste by type of packaging, recycling rate of municipal waste, generation of waste excluding major mineral wastes. The results of this study show that changes in the generation of municipal waste have a significant positive effect on gross domestic energy consumption in the EU in the period 2007-2016. Most likely this may be due to the development of Waste-to-Energy (WtE) technologies. WtE technologies are increasingly presented as an attractive option to solve not only the pressing waste disposal problems but several other challenges simultaneously: shortages in power generation, limited space for landfills, and greenhouse gas emissions from inappropriate waste disposal. However, the introduction of WtE technologies is often jeopardized by common obstacles such as missing tariff systems to fund investments and operation costs, weak enforcement of environmental laws and limited qualified staff to run the installed systems in an efficient and effective manner.

Key-Words: - circular economy, European Union, multiple regression, consumption, energy, generation of municipal waste

1 Introduction

Until the second half of the twentieth century, the development of the economy and society was strongly influenced by the intensive use of available natural resources, which directly influenced the environment. These effects, of which some are irreversible, encourage people to rethink the effects of economic development. The United Nations has developed the concept of sustainable development. It is defined as development that meets the needs of the present, without prejudice to the ability of future generations to meet their own needs [1].

The three components of sustainable development (economic growth, social integration and environmental protection) are aimed at ensuring the preconditions for the well-being of states and their citizens, by eradicating poverty, raising living standards, reducing social inequalities in the management of natural resources. The global nature of the concept of sustainable development was considered at the United Nations Summit in September 2015, when the 2030 Agenda for Sustainable Development was adopted [2]. This key document aims to achieve goals such as eradicating poverty and hunger, ensuring access to education and health services, and protecting the environment by 2030, which are considered the basics of sustainable development.

These initiatives, supported by the European Union since the beginning of the 21st century, have been and remain central to the European Commission, which is working to develop and implement the necessary measures to achieve the 2030 Agenda for Sustainable Development. In this regard, at the end of 2016, the European Commission reported on the implementation of the 2030 Agenda, which includes sustainable development goals within its current priorities, and plans to extend it for a longer period, focusing on sectoral development, starting with 2020 [3].

The transition from the current economy, characterized by linearity (based on the extensive use of natural resources that affect the environment and generate waste), in the direction of a circular economy is envisaged by the European Commission. On December 2, 2015, the European Commission introduced a new circular economy package. The goal of the Package is to stimulate Europe's transition to a circular economy. The package aims to improve the social welfare of the European Union by creating new jobs, promoting sustainable economic growth and enhancing global competitiveness. In order to facilitate the transition process, the European Commission proposes an Action Plan that covers all phases of the product life cycle: from production and consumption to waste management. In addition, this plan, based on measures based on the idea of closed cycles, is aimed at managing the market for secondary raw materials. As part of this Action Plan, you can identify a number of activities that will be aimed at reducing market barriers in five specific sectors: 1) plastics; 2) food waste; 3) critical raw materials (these are raw materials that are economically and strategically important for the European economy, but have a high risk associated with its supply); 4) construction and dismantling; 5) biomass and biological products.

The goal of a circular economy is to maintain the value of products, materials and resources in the economy for as long as possible and minimize the generation of waste. A circular economy should lead to lower energy consumption and carbon dioxide emissions, modernize and transform the economy and support job creation.

The legislative package on the circular economy presented by the European Commission contains an action plan and a list of proposals that make changes to the actual legal structure [3]. The initiative of the European Commission was adopted by member countries such as the Netherlands and Finland, which have already published their strategies for transition to a circular economy by 2050 [4, 5]. In December 2017, Bulgaria announced that some of its priorities for the EU presidency are programs for the circular economy and eco-innovation [6].

2 Literature review

Economic indicators based on traditional national accounts, such as GDP, do not measure the efficiency of resource use, and according to these indicators it is impossible to control the contribution of resource savings to the welfare of the state.

To assess the impact of a circular economy on the growth dynamics of the European Union economy, it is necessary to select indicators. Currently, there are many models and concepts of indicators of the EU circular economy.

In recent debate on the CE, the Ellen MacArthur Foundation [7] advocate an initial approach to circular economy indicators based on existing metrics of:

1) **Resource productivity** (Amount of GDP produced per tonne of DMI. Direct Material Input (DMI) comprises all materials with economic value which are directly used in production and consumption activities. DMI equals the sum of domestic extraction and direct imports.)**.**The advantage of this model is that the data is accessible and transparent; disadvantages lie in the fact that this model is strongly influenced by the industrial structure in a given country, and this weight of resource productivity is not directly related to environmental impact.

2) **Circular activities.** This refers to the level of remanufacturing, sharing and other relevant activities. However, since such data are not readily available, recycling rate and eco-innovation indexes can serve as proxy indicators.

3) **Waste generation**. Two potential metrics are waste generated per GDP output (excluding major mineral waste) and municipal waste generated per capita.

4) **Energy and greenhouse gas emissions** can be represented by metrics of renewable energy use and greenhouse gas emissions per GDP output.

The EU Resource Efficiency scoreboard (EURES) [8] indicators show progress towards increased resource productivity in individual Member States and the European Union. EURES uses the statistics from Eurostat, the European Environment Agency (EEA)and other EU/international sources.

It uses a three-tiered approach:

1. Overall lead indicator for "resource productivity";
2. Second-tier "dashboard" of complementary macro indicators for materials, land, water and carbon.
3. Third tier of theme-specific indicators to measure progress towards key thematic objectives, and the actions and milestones set out in the EU Roadmap to a resource efficient Europe.

EURES is one response to the recommendations of EREP [9] to apply indicators that accurately show progress towards a r esource-efficient economy. These should include indicators that cover resource use in the production chain, both in Europe and globally, providing insights and raising public awareness on the global effects of EU production and consumption. Such indicators should help put in place measures to ensure reduction of the environmental impacts of production and consumption, taking into account differences in economic structure. EREP also recommended that resource efficiency indicators should be considered in measuring social and environmental progress beyond GDP. It was also recognised that there may be a distinction between the efficient and sustainable use of non-renewable and renewable materials.

However, in recent years the European Union has chosen to use the following indicators of circular economy. The monitoring framework on the circular economy as set up by the European Commission consists of 10 indicators, some of which are broken down in sub-indicators.

These indicators were selected in order to capture the main elements of a circular economy. The list is constructed to be short and focused. It uses available data while also earmarking areas where new indicators are in the process of being developed, in particular for green public procurement and food waste.

About half of the indicators in this framework come from Eurostat; others are produced by the Joint Research Centre (JRC) and the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW). The indicator on patents comes from the European Patent Office [10].

These 10 indicators, whose data are available in the Eurostat database, are divided into the following four thematic areas:

- Production and consumption;
- Waste management;
- Secondary raw materials;
- Competitiveness and innovation.

The area of the production and consumption comprises 4 indicators:

- Self-sufficiency of raw materials for production in the EU;
- Green public procurement (as an indicator for financing aspects);
- Waste generation (as an indicator for consumption aspects);
- Food waste.

Monitoring the production and consumption phase is essential for understanding progress towards the circular economy. Households and economic sectors should decrease the amount of waste they generate. In the longer term, this behaviour may contribute to an increasing self-sufficiency of selected raw materials for production in the EU [10].

The area of the waste management comprises 2 indicators:

- Recycling rates (the share of waste which is recycled);

- Specific waste streams (packaging waste, biowaste, e-waste, etc.).

Increasing recycling is part of the transition to a circular economy. This area focuses on the share of waste which is recycled and actually returned into the economic cycle to continue creating value [10].

The area of the secondary raw materials comprises 2 indicators:

- Contribution of recycled materials to raw materials demand;
- Trade of recyclable raw materials between the EU Member States and with the rest of the world.

To close the loop, material and products need to be re-introduced into the economy, for example in form of new materials or products. Recycled materials replace newly extracted natural resources, reduce the environmental footprint of production and consumption and increase the security of the future supply of raw materials [10].

The area of the competitiveness and innovation comprises 2 indicators:

- Private investments, jobs and gross value added;
- Patents related to recycling and secondary raw materials as a proxy for innovation.

The circular economy contributes to the creation of jobs and growth. The development of innovative technologies improves product designs for easier re-use and promotes innovative industrial processes [10].

In our opinion, all the studies on the impact of the indicators of the circular economy on macroeconomic indicators are concentrated mainly on one country or in a specific economic area. In this regard, in this paper we consider the impact of the indicators of the circular economy on the gross inland consumption of the energy of the European Union.

Gross inland energy consumption in the EU-28 in 2016 was 1 640 Mtoe, 0.7 % higher than in 2015 (Figure 1). It was relatively stable during the period 1990-2010, with a strong decrease in 2009 as a result of the financial and economic crisis.

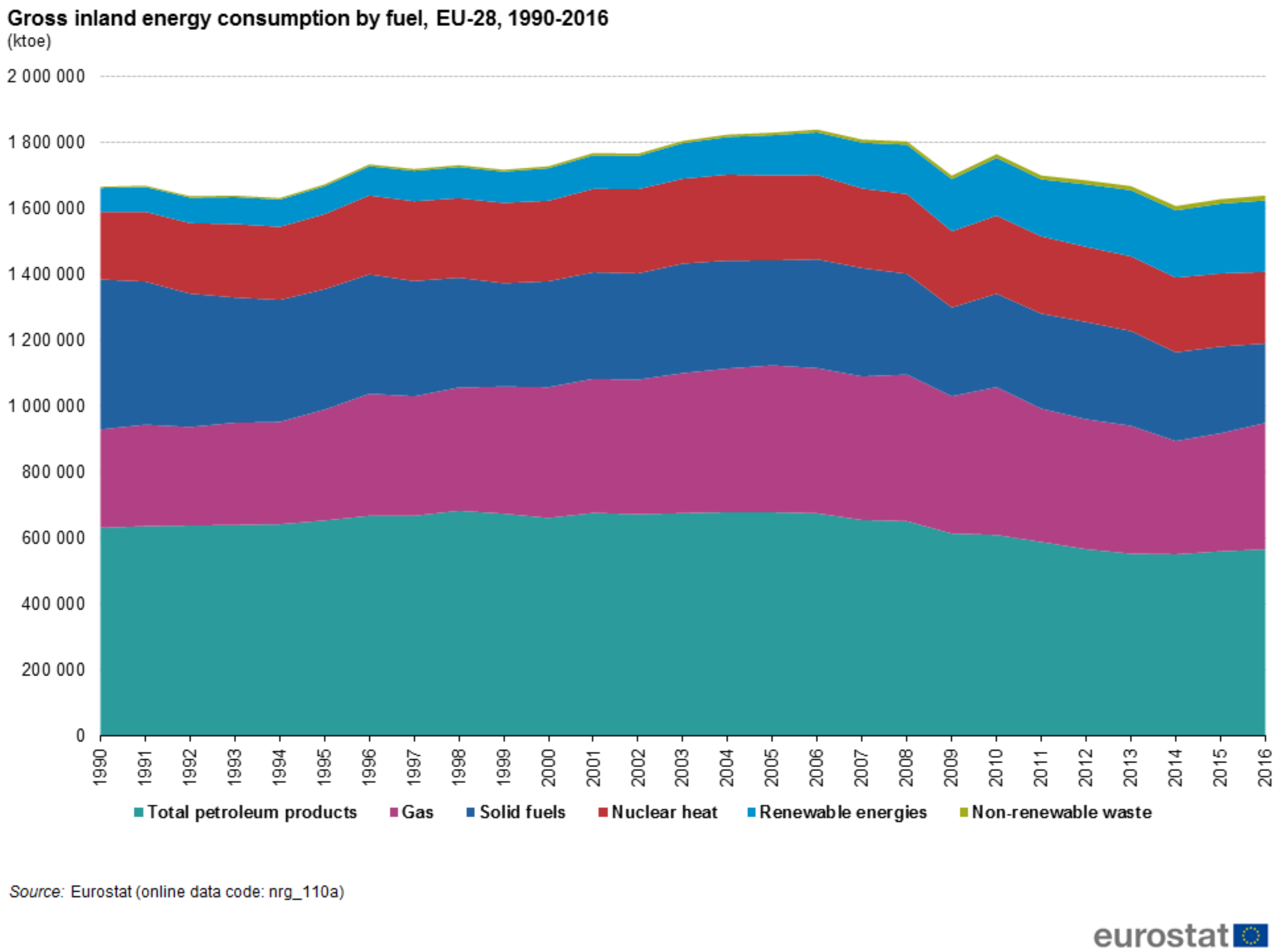

Fig. 1. Gross inland energy consumption, EU-28, 1990-2016 (ktoe)

In 2009, gross inland energy consumption decreased by 5.8 % compared to 2008, with the sharpest decrease in solid fuels (11.9 %), followed by gas (6.4 %) and petroleum products by 5.7 % each

(Figure 2). There was a recovery in 2010, when gross inland energy consumption increased by 3.8 %, afterwards followed by consecutive decreases until 2015 when it started increasing again. The gross inland consumption in 2013 was just below the level recorded in 1990 and in 2016 it was 1.7 % below the 1990 levels. A 47.0 % drop in solid fuels and oil products with 10.3 % contributed the most to the 2016 decrease, while renewable energies increased considerably (over 200 %) compared to 1990. In fact, the gross inland energy consumption in the EU-28 in 2014 was the lowest since the historic time series allows for comparison (since 1990).

As for the structure of gross inland energy consumption in 2016, petroleum products held the biggest share (34.6 %), followed by gas (23.3 %) and solid fossil fuels (14.7 %), which means that 71.5 % of all energy in the EU-28 was produced from fossil sources (coal, crude oil, natural gas). The share of nuclear heat and renewable energies accounted for 13.2 % each (Figure 3).

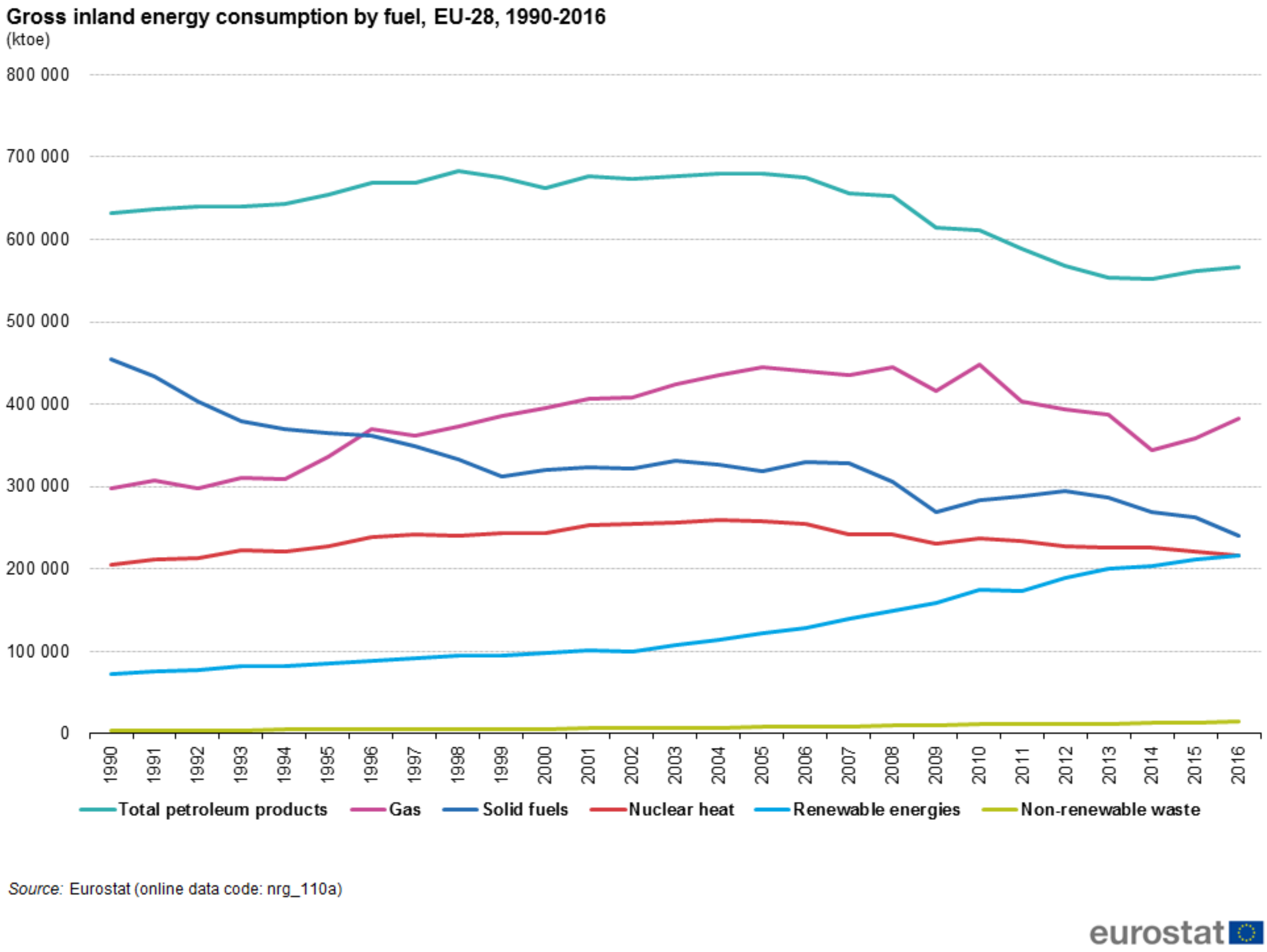

Fig. 2. Gross inland energy consumption, EU-28, 1990-2016 (ktoe)

The mixture of fuels and their shares in gross inland energy consumption in different countries depends on the natural resources available, the structure of their economies and also national choices in energy systems.

Only in three EU countries is the share of fossil fuels in gross inland energy consumption (Figure 6) below 50 % (Sweden 29.6 %, Finland 46.6 % and France 48.4 %). It should be noted that France and Sweden are the countries with the highest contribution of nuclear heat to the gross inland energy consumption (41.2 % and 32.4 % respectively).

In 2016, the only country where over half of gross inland consumption was covered by solid fossil fuels (Figure 3) was Estonia (59.4 %). The EU-28 average was 14.7 %. The smallest shares of solid fossil fuels in gross inland energy consumption (under 2 %) in 2016 were observed in Luxembourg, Latvia, Cyprus and Malta.

The largest shares of total petroleum products in gross inland energy consumption were observed in

Cyprus (93.1 %), Malta (78.6 %) and Luxembourg (62.8 %). This is due to specific national characteristics: Malta and Cyprus are small islands while consumption in Luxembourg is affected by "fuel tourism" due to lower prices of fuels used in the transport sector.

Natural gas accounted for shares varying from 38.4 % in the Netherlands to under 2 % in Sweden, Cyprus and Malta. Natural gas was also an important energy source in Italy, the United Kingdom and Hungary with shares of over 30 %, and Ireland reaching nearly the 30 % mark.

In two countries, Latvia and Sweden, renewable energies accounted for over 35 % of their gross inland energy consumption in 2016 (37.0 % and 36.4 % respectively). The lowest share of renewable energy in gross inland consumption was in Malta (3.4 %), the Netherlands (4.7 %) and Luxembourg (5.3 %).

In 2016, there were 14 Member States with nuclear power plants. The highest nuclear share was in France (a 41.2 % share of nuclear heat in gross inland energy consumption), followed by Sweden (32.4 %), Slovakia (23.4 %), Bulgaria (21.9 %) and Slovenia (21.4 %).

In 2016, gross inland consumption in Luxembourg and Finland was over 6 toe per capita. In Romania and Malta, consumption was under 2 toe per capita (Figure 4, 5). This indicator is influenced by the structure of industry in each country, the severity of the winter weather, as well as by other factors, such as fuel tourism in the case of Luxembourg. The EU-28 average in 2016 is 3.2 toe per capita.

Between 1990 and 2016, the EU-28 average decreased by 8.5 %. However, at national level, the evolution ivaries. The biggest increase in gross inland consumption per capita between 1990 and 2016 was observed in Portugal (23.5 %), followed by Austria (18.9 %) and Slovenia (15.1 %), while the biggest decrease was observed in Lithuania (43.5 %), Romania (34.5 %) and Germany (32.1 %).

Figure 6 shows the structural split of gross inland energy consumption in the EU-28 by main categories of the energy balance. In 2016, the biggest share of energy in EU-28 was used in energy transformation (25.1 %), followed by the transport sector (22.4 %), households (17.4 %), industry sector (16.9 %), services (9.1 %), non-energy use (6.0 %) and other (3.2 %). The proportion of main categories of uses is relatively unchanged over the period 1990-2016.

3 Methodology

In this study, we evaluate the impact of circular economy indicators on gross inland consumption of the energy.

The purpose of these studies was to identify indicators of a circular economy that have the greatest impact on the gross inland consumption of the energy of the European Union. The study was conducted using the software package Statgraphics Centurion. The baseline data for the study were data from the official EUROSTAT website for the period from 2007 to 2016 [11].

As a method of econometric modeling, we chose correlation and regression analysis, which allows you to choose from the entire set of factors considered the most significant.

This study examined the effect of indicators of circular economy on the gross inland consumption of the energy in EU from 2007 to 2016. In analyzing the effect of the independent variables on the dependent variable (gross inland consumption of the energy) multivariate regression analysis was used.

As a dependent indicator (Y) was taken gross inland consumption of the energy (thousand tonnes of oil equivalent (TOE)), factor signs (X) were the following:

X_1 –Generation of municipal waste per capita, kg per capita;

X_2 –Domestic material consumption per capita, tonnes per capita;

X_3 –Resource productivity, Euro per kilogram;

X_4 –Recycling of biowaste, kg per capita;

X_5 – Recycling rate of packaging waste by type of packaging, % Packaging;

X_6 – Recycling rate of municipal waste, %;

X_7 – Generation of waste excluding major mineral wastes, kg per capita.

Table 1 presents a summary statistics for each of the selected data variables. It includes a summary of descriptive statistics of the variables, which include sample mean, standard deviation, skewness and kurtosis.

Of particular interest here are the standardized skewness and standardized kurtosis, which can be used to determine whether the sample comes from a normal distribution

Values of these statistics outside the range of -2 to +2 indicate significant departures from normality, which would tend to invalidate many of the statistical procedures normally applied to this data.

In this study variables show the standardized skewness and standardized kurtosis are out of this range.

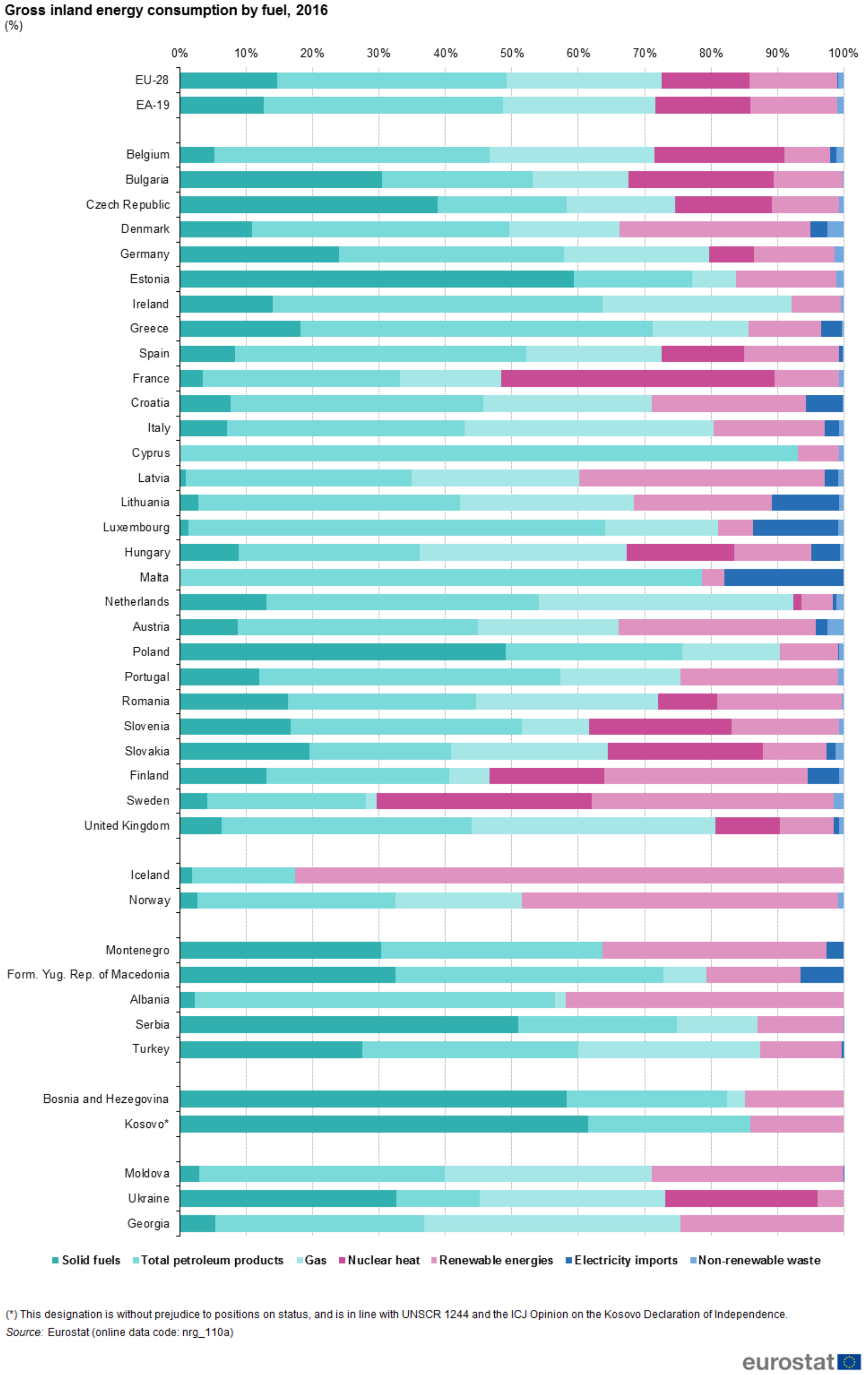

Fig. 3. Gross inland energy consumption by fuel, 2016 (%)

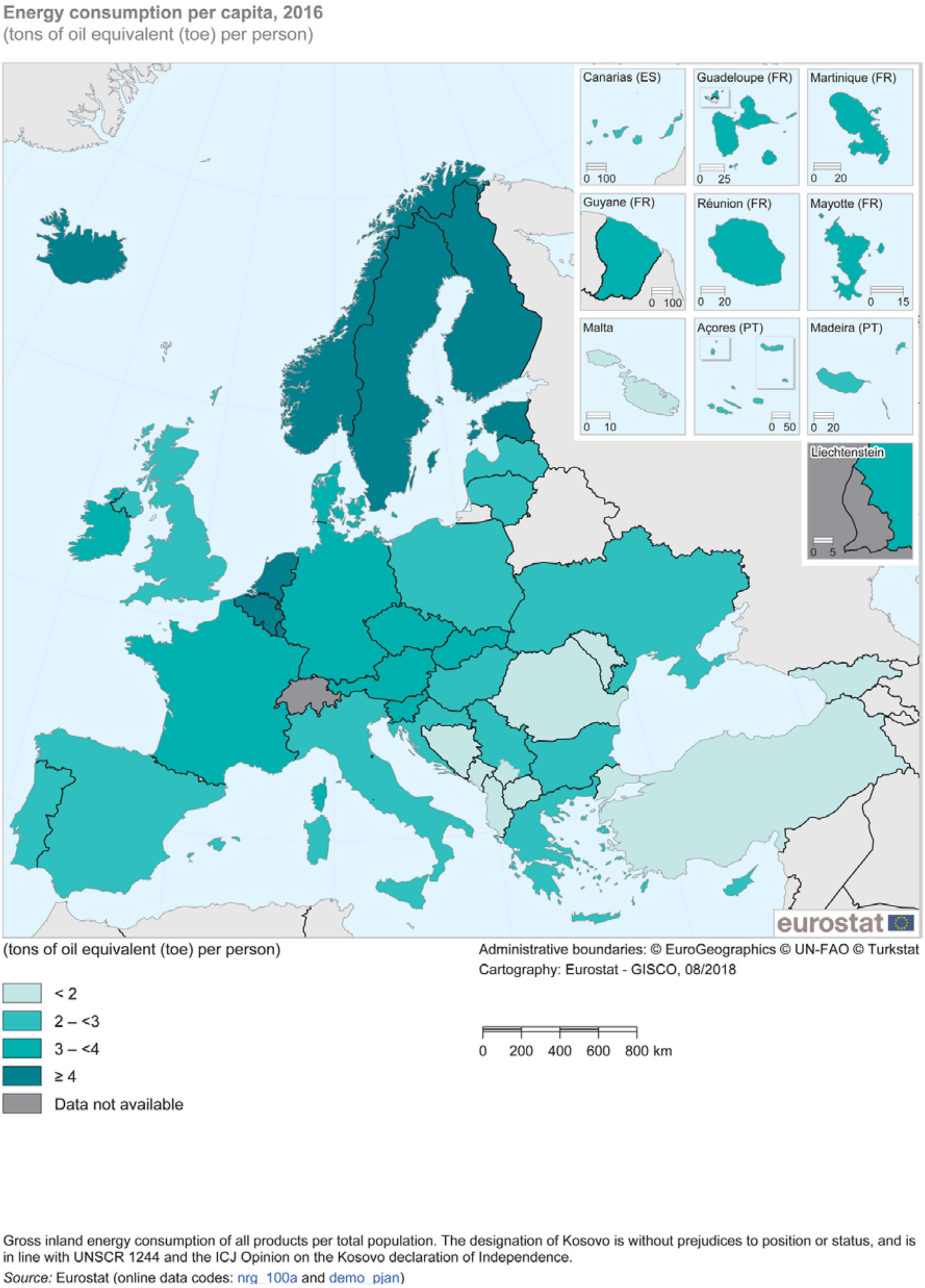

Fig. 4. Energy consumption per capita, 2016, (toe per capita)

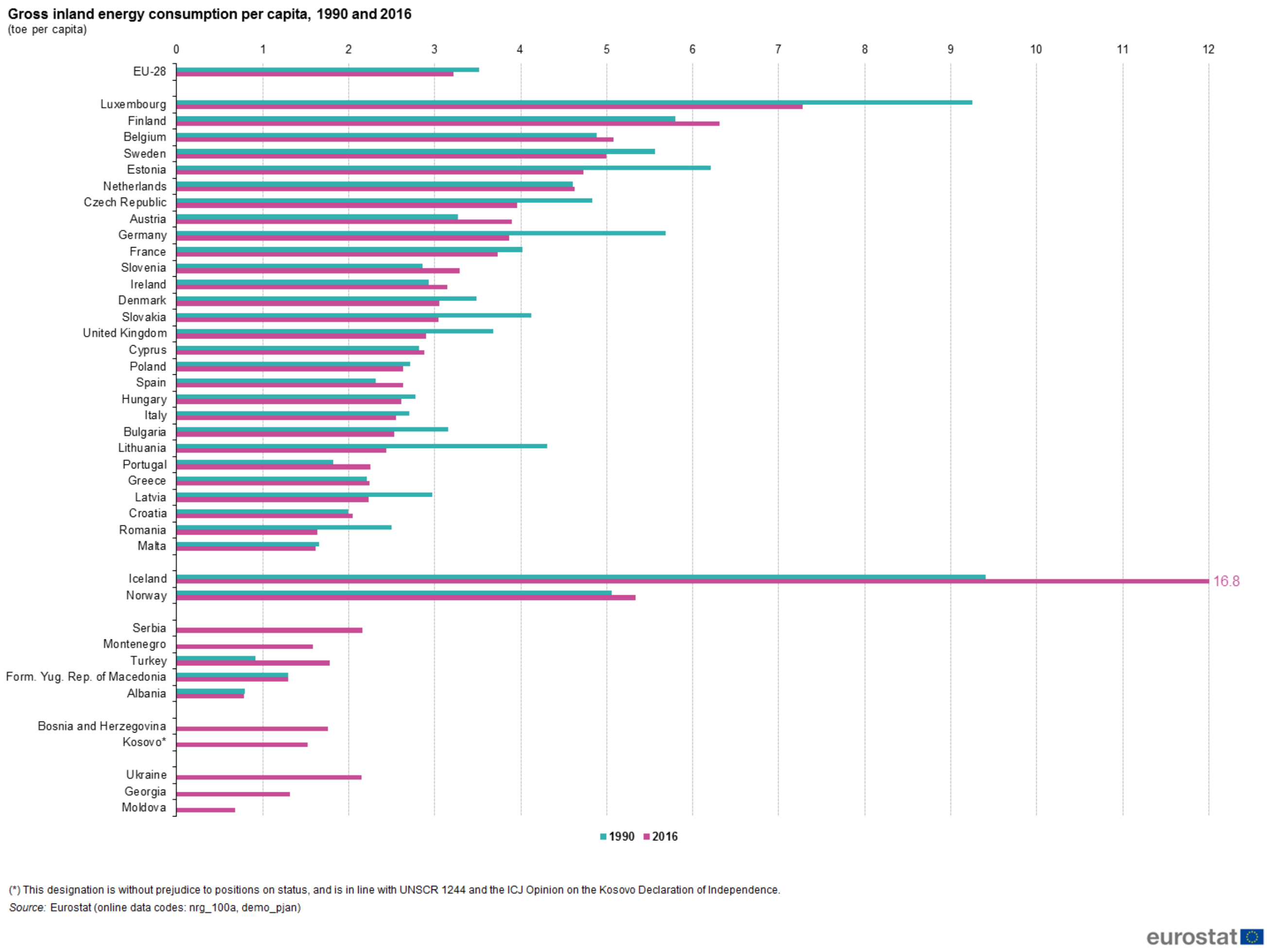

Fig. 5. Gross inland energy consumption per capita, 1990 and 2016 (toe per capita)

Table 1 Summary Statistics

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Average	13539400	496,4	14,343	1,828	70,5	63,77	40,23	1746,4
Standard deviation	845909	17,652	1,291	0,162	4,275	2,456	3,540	60,612
Coeff. of variation	6,248%	3,556%	9,0%	8,885%	6,064%	3,851%	8,800%	3,471%
Minimum	12329200	478	13,245	1,567	64	59,2	35	1695
Maximum	14937100	524	16,728	2,028	78	67	45,3	1848
Range	2607920	46	3,483	0,462	14	7,8	10,3	153
Stnd. skewness	0,774	0,677	1,608	-0,712	0,420	-0,985	0,080	1,447
Stnd. kurtosis	-0,286	-0,912	0,152	-0,649	-0,332	-0,109	-0,859	-0,425

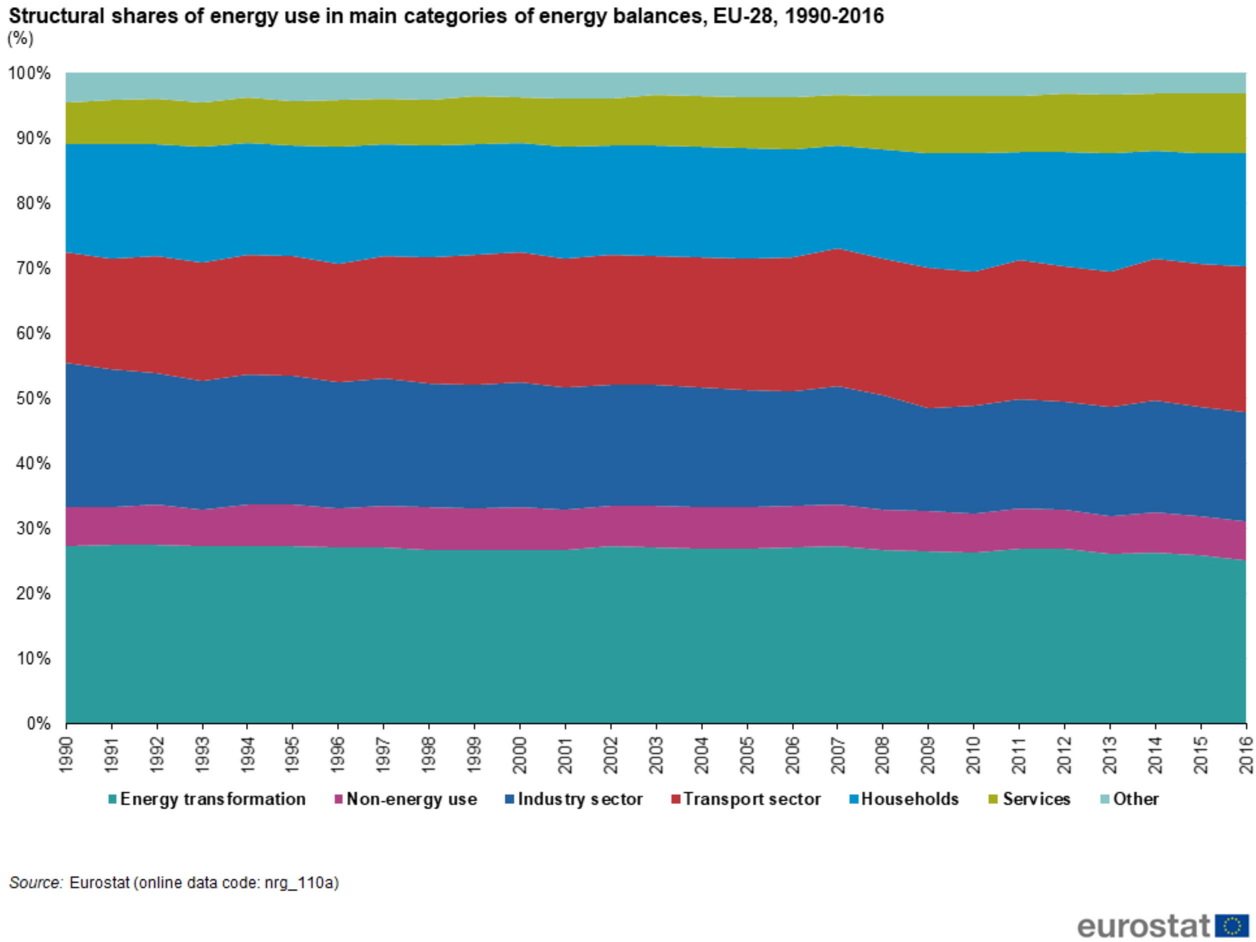

Fig. 6. Structural shares of energy use in main categories of energy balances, EU-28, 1990-2016 (%)

4 Results and discussions

Multicollinearity is a statistical term for the existence of a high order linear correlation amongst two or more explanatory variables in a regression model. In any practical context, the correlation between explanatory variables will be non-zero, although this will generally be relatively benign in the sense that a small degree of association between explanatory variables will almost always occur but will not cause too much loss of precision.

The presence of multicollinearity usually results in an overstatement of the standard error, i.e. the standard error tends to be large, leading to small “t” value and a high coefficient of determination. The usual procedure when multicollinearity exists is to drop the offending variable or alternatively to drop the variable that provides lesser contribution towards model improvements. A simple procedure to determine which variable to drop is to calculate the correlation matrix. The correlation matrix on Figure 7 represents the correlation coefficient for the variables used in this study.

As all the studies on the impact of the indicators of the circular economy on macroeconomic indicators are concentrated mainly on one country or in a specific economic area, quantifying of the indicators of the circular economy on the macroeconomic indicators of the European Union was the focus of the discussion.

The most important task in the construction of multiple linear regression is the correct selection of factors included in this equation. In solving this problem, the following schemes have gained the most widespread use: the method of Forward Stepwise Selection and the method of Backward Stepwise Selection i.e. the elimination of factors from its full set.

Forward Stepwise Selection is performs a forward stepwise regression. Beginning with a model that includes only a constant, the procedure brings in variables one at a time provided that they will be statistically significant once added. Variables may

also be removed at later steps if they are no longer statistically significant.
Backward Stepwise Selection is performs a backward stepwise regression. Beginning with a model that includes all variables, the procedure removes variables one at a time if they are not statistically significant. Removed variables may also be added to the model at later steps if they become statistically significant.
Fitting the model using the original data showed 6 minor variables. To remove them from the model, the analysis parameters can be used to perform the reverse step-by-step selection.
Backward selection begins with a model involving all the variables specified on the data input dialog box and removes one variable at a time based on its statistical significance in the current model. At each step, the algorithm removes from the model the variable that is the least statistically significant. Removal of variables is based on either a P-to-enter test. In the former case, if the least significant variable has an P-value large than 0,05, it will be removed from the model. When all remaining variables have less P-value, the procedure stops.
In first step the highest P-value on the independent variables is 0,235, belonging to X_2. Since the P-value is greater to 0,05, that term is not statistically significant at the 95,0% or higher confidence level. Consequently, X_2 must be removing from the model.
In the second step the highest P-value on the independent variables is 0,135, belonging to X_4. Since the P-value is greater to 0,05, that term is not statistically significant at the 95,0% or higher confidence level. Consequently, X_4 must be removing from the model.
In the third step the highest P-value on the independent variables is 0,309, belonging to X_6. Since the P-value is greater to 0,05, that term is not statistically significant at the 95,0% or higher confidence level. Consequently, X_6 must be removing from the model.
In the fourth step the highest P-value on the independent variables is 0,208, belonging to X_3. Since the P-value is greater to 0,05, that term is not statistically significant at the 95,0% or higher confidence level. Consequently, X_3 must be removing from the model.
In the fifth step the highest P-value on the independent variables is 0,095, belonging to X_5. Since the P-value is greater to 0,05, that term is not statistically significant at the 95,0% or higher confidence level. Consequently, X_5 must be removing from the model.
In the sixth step the highest P-value on the independent variables is 0,068, belonging to X_7. Since the P-value is greater to 0,05, that term is not statistically significant at the 95,0% or higher confidence level. Consequently, X_7 must be removing from the model.
The algorithm then stops, as the highest P-value on the independent variables is 0,0002, belonging to X_1. Since the P-value is less than 0,05, that term is statistically significant at the 95,0% confidence level. Consequently, it is a final model.
Table 2 shows the results of fitting a multiple linear regression model to describe the relationship between Y and 7 independent variables.
Table 3 shows the statistical significance of each variable as it was added to the model. Since the P-value in the ANOVA table is less than 0,05, there is a statistically significant relationship between the variables at the 95,0% confidence level.
The estimation result of the independent variables to the dependent variable is shown in Table 4.
Based on the estimation results presented in Table 1, the following equation was obtained:

$$Y = -136886 + 3703{,}56 \cdot X_1$$

The R-Squared statistic indicates that the model as fitted explains 84,639% of the variability in Y. The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 82,7189%.The standard error of the estimate shows the standard deviation of the residuals to be 29540,5. This value can be used to construct prediction limits for new observations by selecting the Reports option from the text menu. The mean absolute error (MAE) of 21887,2 is the average value of the residuals. The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in your data file.
Since the P-value is greater than 0,05, there is no indication of serial autocorrelation in the residuals at the 95,0% confidence level.
The result of the regression estimation showed that if generation of municipal waste per capita, increases by 1 kg per capita, gross inland consumption of the energy will rise by 3703,56 TOE.
This is associated with a decrease in the disposal of municipal waste and an increase in the volume of their utilization - incineration, recycling and composting [12, 13]. Additional energy costs are spent on these activities, which are shown by the regression relationship between generation of

municipal waste per capita and gross inland consumption of the energy.

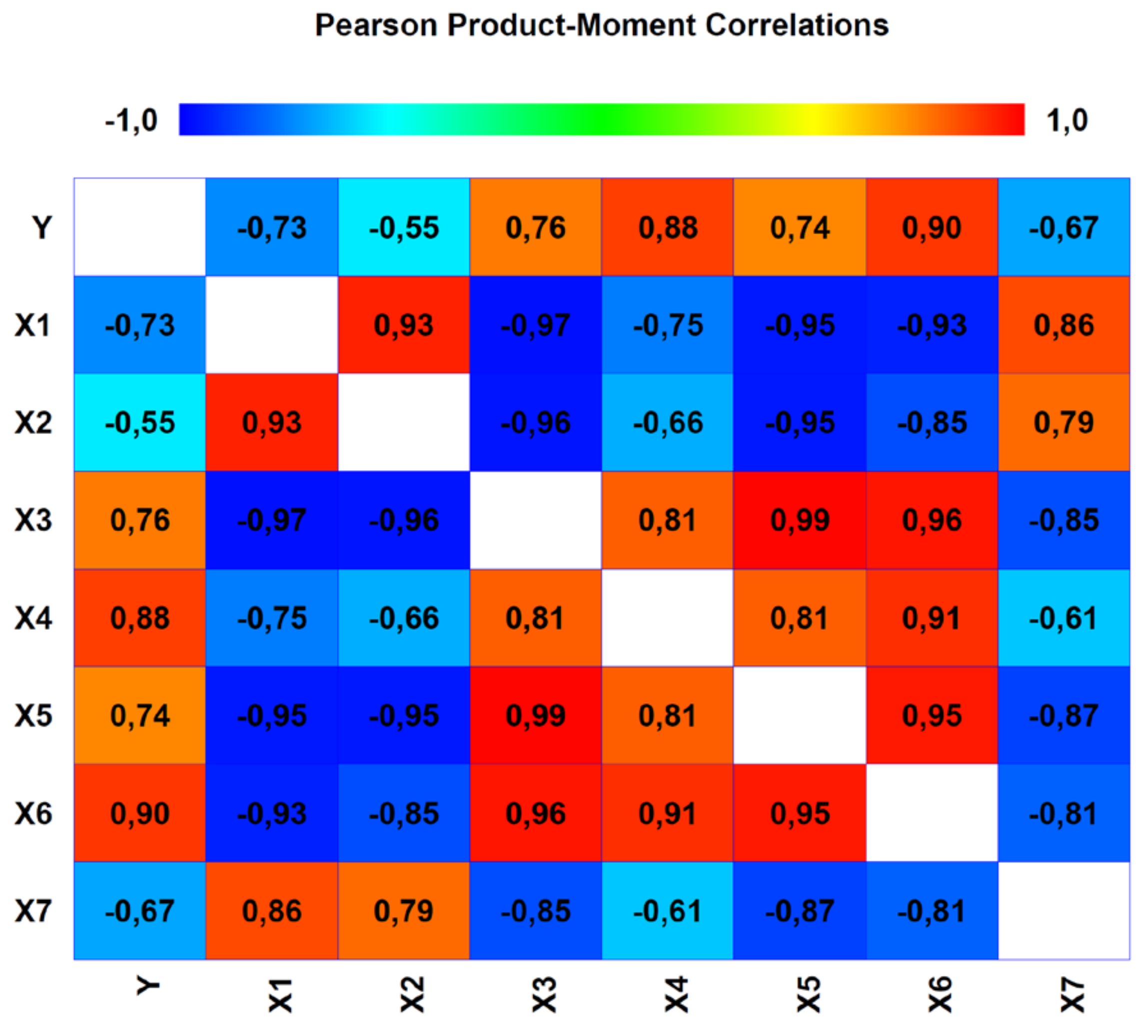

Fig. 7. Correlation matrix

Table 2 Estimation results of the dependent variable: Gross inland consumption of the energy

Parameter	*Estimate*	*Standard Error*	*T-Statistic*	*P-Value*
CONSTANT	-136886	277062	-0,494064	0,6345
X_1	3703,56	557,825	6,63928	0,0002

Table 3 ANOVA for Variables in the Order Fitted

Source	*Sum of quares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
X_1	3,84661E10	1	3,84661E10	44,08	0,0002
Model	3,84661E10	1			

Table 4 Analysis of Variance

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Model	3,84661E10	1	3,84661E10	44,08	0,0002
Residual	6,98113E9	8	8,72641E8		

Total (Corr.)	4,54472E10	9			
R-squared = 84,639 percent					
R-squared (adjusted for d.f.) = 82,7189 percent					
Standard Error of Est. = 29540,5					
Mean absolute error = 21887,2					
Durbin-Watson statistic = 2,61141 (P=0,7402)					
Lag 1 residual autocorrelation = -0,317766					

4 Conclusion

The policy of a ci rculation economy in the EU is vital in terms of both economic and energy aspects. Based on the research presented in this paper, some conclusions were made.

The results of this study show that changes in the generation of municipal waste have a significant positive impact on the gross inland consumption of the energy in the EU in the period 2007-2016. Most likely this may be due to the development of Waste-to-Energy (WtE) technologies.

The tremendous rise in municipal solid waste (MSW) in the fast-growing cities of EU have led to increasing public concerns with regards to the resultant health and environmental impacts. In the quest to modernise their waste management systems, local decision makers frequently face the question of whether they should invest in Waste-to-Energy (WtE) technologies. WtE technologies are increasingly presented as an attractive option to solve not only the pressing waste disposal problems but several other challenges simultaneously: shortages in power generation, limited space for landfills, and greenhouse gas emissions from inappropriate waste disposal. However, the introduction of WtE technologies is often jeopardized by common obstacles such as missing tariff systems to fund investments and operation costs, weak enforcement of environmental laws and limited qualified staff to run the installed systems in an efficient and effective manner.

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