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Greenhouse gas emissions as regards the sectors in the European Union countries

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Abstract*. The hypothesis, that the emission of greenhouse gas in the whole EU, as well as in particular member countries is decreasing, was verified in this article. Due to the fact that emission depends on the number of inhabitants, it was calculated with regard to 1000 people and then the similarities of greenhouse gas emissions in the EU countries with various economic sectors were researched. Another hypothesis, concerning the fact that emission depends on the geographical position and historical conditions was verified. Czekanowski's Method was used to make a division for homogeneous countries as regards the greenhouse gas emissions from various economic sectors.*

The analysis proved that the greenhouse gas emissions are decreasing in the whole EU, except for two countries where the emissions are rising. The conclusions were drawn after the division with the use of Czekanowski's Method, the emission of greenhouse gas neither depends on geographical position, nor on historical conditions.

Keywords*: greenhouse gas emissions, European Union, Czekanowski's Method.*

Raktažodžiai*: šiltnamio efektą sukeliančios dujų emisijos, Europos Sąjunga, Czekanowskio metodas.*

Introduction

At the end of the 20th century European Union started to put greater and greater emphasis on environmental protection. In 1987, G.H. Brundtland's Commission of Environment and Development published the report entitled: Our Common Future (www 4), where issues concerning balanced development were included. The balanced development was defined as the process of changes which ensures the fulfillment of present generation's needs without lessening the developmental chances of future generations, thanks to consolidated actions in the scope of economic and social development, as well as in the scope of environment.

Since 1987 the problem of environmental protection was touched upon many times. The most important documents of European Commission, as regards the problem of environmental protection, are as follows:

- Agenda 21
- Europe 2020
- declaration: The Future We Want,
- Developmental Agenda 2030: Transforming Our World.

According to many authors, the emission of greenhouse gases is the main reason of climate warming (Kundzewicz 2008). Most frequently, the problem of climate warming is discussed globally, i.e.: in the context of whole Europe or with the division for particular European countries. In the present article the statistic and econometric analysis of greenhouse gas emissions was conducted. It was done globally, as well as with the division for economic sectors of the EU countries. There are 6 economic sectors that can be distinguished according to IPCC classification (Intergovernmental Panel on Climate Change): energy, manufacturing and construction, transport, industrial processes, agriculture and waste.

The hypothesis, that the emission of greenhouse gases in the whole EU, as well as in particular member countries is decreasing, was verified in this article. In the before mentioned economic sectors the decrease of greenhouse gas emissions is visible as well. The emission depends also on the geographical position of countries and their historical conditions- in the developed countries the emission is lower and in the central- east European countries the emission is higher.

The emission of greenhouse gas is stated in CO_2 equivalent and given in thousand tones. The data is taken from the Central Statistical Office of Poland website (Główny Urząd Statystyczny (www 6)).

Greenhouse gas emission in the EU

The European Union introduces many regulations with regard to greenhouse gas emissions, introduces the limits of gas emission for particular countries and the penalties for the greatest poisoners (www 5). Greenhouse gases are gaseous components of the atmosphere that absorb solar energy reflected from the earth,s surface

as infrared radiation. This energy is transferred to the major non-greenhouses (nitrogen and oxygen) resulting in an overall temperature increase in the lower atmosphere (de Klein 2008). All off the above mentioned actions should lead to decreased emission of greenhouse gases into atmosphere. In Fig.1. there is a presentation of greenhouse gas emissions in the EU countries (28) between 2004 and 2013.

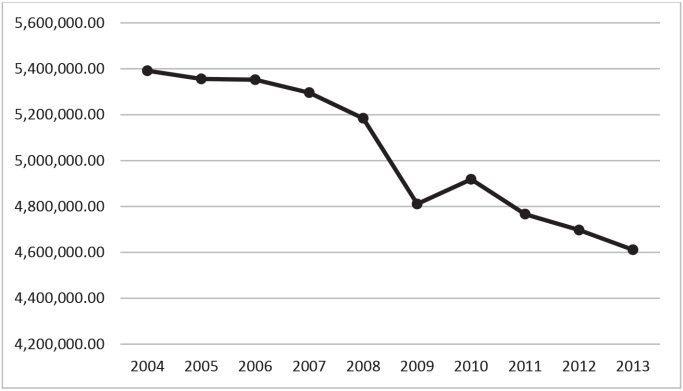

Fig. 1 **Greenhouse gas emissions in the EU countries (28) between 2004 and 2013 in CO2 equivalent in thousand tones.**

Source: own study.

The emission of greenhouse gas in the EU between 2004 and 2013 was decreasing systematically. 2010 was an exception, when the emission was rising. Perhaps the financial crisis from 2008 influenced such a situation. Due to the crisis, the economy of the EU slowed down and as a result the greenhouse gas emission was reduced. Next year, when the economy started to develop quicker the emissions were higher again. In the whole research period the greenhouse gas emissions were decreased by 14,5%. In October 2014, the EU established new objectives as regards the climate and energy. One of the objectives is the reduction of greenhouse gas emissions by 40% till 2030, in comparison to 1990 (www 1).

The average pace of changes of greenhouse gas emissions (calculated according to pattern 1 (Ostasiewicz 2001)) in the researched period equaled to 0,983. Which means that the greenhouse gas emission was decreasing year by year on average by 1,7%.

$$\bar{\imath}_G = \sqrt[n-1]{i_{n/1}}\,, \quad (1)$$

In 2013, the EU reduced emission of greenhouse gas almost by 20% (www2). Assuming the calculated pace of changes, the objective concerning the reduction of

greenhouse gas emissions will be obtained in the EU without the problem. However, assumption that such a pace of changes will be held for next 17 years is unjustified.

The division of greenhouse gas emissions as regards the economic sectors, which are the reason of those emissions, shows that energy industry (Fig.2.) holds the major responsibility.

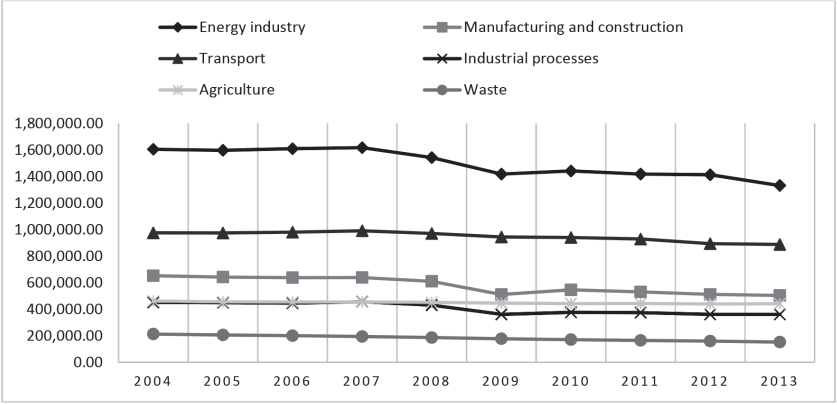

Fig.2. **Greenhouse gas emissions as regards the economic sectors in the EU (28) between 2004 and 2013 in CO_2 equivalent in thousand tones.**

Source: own study

The greenhouse gas emission in all of the economic sectors decreased between 2004 and 2009. The most prominent decrease was in waste sector- by 28,4% and the lowest decrease was in agriculture- only by 4,5%.

The mean pace of changes was as follows: agriculture- 0,955, transport- 0,91, energy industry- 0,83, industrial processes- 0,798, manufacturing and construction- 0,772 and waste- 0,716.

The emissions of carbon dioxide, methane and nitrous oxide from agriculture together account for approx-imately one-fifth of the annual increase in radiative forcing of climate change (Cole 1997).

Reducing greenhouse gas (GHG) emissions from motor vehicles is a major challenge for climate policy. Modest increases in vehicle efficiency have been offset by increased total travel, and transportation has accounted for about 40% of the growth in carbon dioxide (CO2) emissions from all energy-using sectors since 1990 (Inventory 2006).

The significant decrease of greenhouse gas emission was in 2009 in energy industry, manufacturing and construction and industrial processes, namely, in all sectors connected with industry.

Greenhouse gas emissions in the EU countries

The greatest issuers of greenhouse gas in the EU are the biggest countries. In Table 1 there are 10 countries emitting the biggest quantity of greenhouse gases in 2004 and in 2013.

Table 1. **Countries emitting the biggest quantity of greenhouse gases in 2004 and in 2013**

	2004	2013
1	Germany	Germany
2	the United Kingdom	the United Kingdom
3	Italy	France
4	France	Italy
5	Spain	Poland
6	Poland	Spain
7	the Netherlads	the Netherlads
8	the Czech Republic	the Czech Republic
9	Romania	Greece
10	Belgium	Belgium

Source: own study

The countries emitting the biggest quantity of greenhouse gases in 2004 and 2013 changed insignificantly. In 2004, as well as in 2013 Germany emitted the most of greenhouse gases, second place was held by the United Kingdom.

The countries, with the lowest emissions in 2004 and in 2013 were: Malta, Cyprus, Latvia and Luxembourg- all of them are small countries. In the whole European Union the greenhouse gas emission decreased by 14,5%, while the particular countries with the most prominent decrease were presented in Table 2.

Table 2. **Countries, which decreased the greenhouse gas emissions in the most prominent way in the EU in 2013, in comparison to 2004.**

	Country	$i_{2013/2004}$
1	Italy	0,713
2	Spain	0,724
3	Romania	0,738
4	Portugal	0,767
5	Finland	0,777
6	Hungary	0,779
7	Belgium	0,779
8	the United Kingdom	0,798
9	Denmark	0,801
10	Croatia	0,830

Source: own study

Italy reduced the greenhouse gas emission the most- by 28,7%. The United Kingdom, as one of the two countries with the highest emissions, reduced the emission by 27,6%. Only two countries of the EU increased the emissions in the researched period, and they were Latvia and Estonia. While Latvia noted the increase only by 2,6%, Estonia noted the increase by 14,6%.

Due to the fact that greenhouse gas emissions depend on the number of inhabitants (the coefficient factor of Pearson's correlation equals respectively: 0,98 for 2004 and 0,96 for 2013) it seems to be reasonable to calculate the emission per one inhabitant. In Table 3, the countries with highest emissions per one inhabitant are presented.

Table 3. **Greenhouse gas emissions in CO_2 equivalent in thousand tones per 1000 inhabitants**

2004			2013		
	Country	CO_2 emission		**Country**	**CO_2 emission**
1	Luxembourg	24,46	**1**	Luxembourg	16,88
2	Ireland	14,64	**2**	Estonia	15,97
3	Finland	14,14	**3**	Ireland	10,63
4	Estonia	13,66	**4**	Finland	10,49
5	the Czech republic	12,23	**5**	the Czech republic	10,42
6	Cyprus	11,51	**6**	Germany	9,73
7	Belgium	11,30	**7**	the Netherlands	9,05
8	Denmark	11,26	**8**	Greece	8,98
9	the Netherlands	10,88	**9**	Denmark	8,63
10	Greece	10,63	**10**	Poland	8,20

Source: own study

Luxembourg is the country emitting the biggest quantity of greenhouse gases as per 1000 inhabitants. In 2004, it was almost 10 thousand tones more than in Ireland. For sure, the high position of Finland and Ireland is an astonishment. In 2004, in top ten of the biggest issuers of greenhouse gases as per 1000 inhabitants there wasn't Germany, nor Poland. But they could be found in the classification from 2013.

In most of the EU countries the greenhouse gas emission as per 1000 inhabitants was reduced in 2013, in comparison to 2004, but there are 3 exceptions: Lithuania- increase by 4%, Estonia- increase by 17% and Latvia with the increase by 19%.

Greenhouse gas emissions with the division for economic sectors in the EU countries

Among the most prominent issuers of greenhouse gas emissions as per 1000 inhabitants small and big countries can be found. In Table 4 and 5 there are presented the biggest issuers as per 1000 inhabitants in division for economic sectors in 2004 and 2013 respectively.

Table 4. **Biggest issuers as per 1000 inhabitants in division for economic sectors in 2004**

	Energy industry	Manufacturing and construction	Transport	Industrial processes	Agriculture	Waste
1	Estonia	Luxembourg	Luxembourg	Belgium	Ireland	the United Kingdom
2	Finland	Finland	Ireland	Slovakia	Denmark	Portugal
3	the Czech Republic	the Czech Republic	Austria	Austria	Luxembourg	Bulgaria
4	Greece	Belgium	Cyprus	Luxembourg	France	Finland
5	Denmark	Slovakia	Belgium	the Czech Republic	Lithuania	Greece
6	Malta	Spain	Finland	Cyprus	Cyprus	Ireland
7	Poland	the Netherlands	Denmark	Greece	Finland	Cyprus
8	Germany	Italy	France	Finland	the Netherlands	Hungary
9	Cyprus	Germany	Sweden	Lithuania	Belgium	Lithuania
10	the Netherlands	Ireland	the Netherlands	the Netherlands	Spain	the Netherlands

Source: own study

Table 5. **Biggest issuers as per 1000 inhabitants in division for economic sectors in 2013**

	Energy industry	Manufacturing and construction	Transport	Industrial processes	Agriculture	Waste
1	Estonia	Luxembourg	Luxembourg	Austria	Ireland	Portugal
2	the Czech Republic	Finland	Austria	Belgium	Denmark	Bulgaria
3	Greece	Germany	Slovenia	Slovakia	Lithuania	the Czech Republic
4	Germany	the Netherlands	Ireland	the Czech Republic	France	Greece
5	Poland	Slovakia	Finland	Cyprus	Luxembourg	Hungary
6	Malta	Austria	Belgium	Luxembourg	Latvia	Cyprus
7	Finland	Belgium	Denmark	Finland	Finland	Finland
8	Bulgaria	the Czech Republic	the Netherlands	Greece	the Netherlands	Lithuania
9	the Netherlands	France	France	Lithuania	Estonia	Latvia
10	Denmark	Spain	Germany	Estonia	Belgium	the United Kingdom

Source: own study

Analyzing Tables 4 and 5, there are visible changes that occurred between 2004 and 2005 in greenhouse gas emissions as per one inhabitant in the EU countries. There is visible as well, which countries have to do the most in particular economic sectors to reduce the greenhouse gas emission. Luxembourg could be found in 2013 in top ten of issuers in four economy sectors. The same situation concerned Belgium, the Czech Republic and the Netherlands. Only Finland was the country which could be noticed in this ranking more times than above countries. Moreover, Finland was the country which could be found in each category of the greatest issuers of greenhouse gas emissions in the EU.

Only 4 countries did not hold any position in this inglorious ranking and they are as follows: Croatia, Romania, Sweden and Italy.

Analysis of similarities between the EU countries as regards the resemblance of greenhouse gas emissions with the division for economy sectors.

In the introduction, there was a hypothesis claiming that some of the countries are characterized by similar structure of greenhouse gas emissions. It results from the similar geographical position or historical similarities. To group the countries from different economy sectors according to the similarities of greenhouse gas emissions the Czekanowki's Method (Czekanowski 1913) was used. The visualization of the results is the Czekanowski's Diagram.

To define Czekanowski's Diagram the following procedure needs to be maintained (Heffner 2007):

1. Defining data matrix,
2. Making the data comparable by using standardization or unitization of variables,
3. Choosing the similarity measure,
4. Calculating the matrices of taxonomic distances,
5. Searching in the matrix the taxonomic distances with minimal and maximum values,
6. Defining the ranges of classes for taxonomic distances values on the basis of chosen empirical area of variability,
7. Preparing disorderly Czekanowski's Diagram,
8. Obtaining orderly Czekanowski's Diagram,
9. Interpreting the results.

All of the calculations and the definition of diagram were made in MaCzek (www 3) programme. While preparing the data, it was standardized according to the pattern (Dziechciarz 2012).

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j}, \quad (i = 1, 2, \ldots, n; j = 1, 2, \ldots, m), \quad (2)$$

where: $\overline{x}_j$ - arithmetic mean of variable x_j,

S_j - standard deviation of variable x_j,

Z_j - standardized value of variable x_j for i-object.

After the data standardization, the matrix of distances of similarities between objects was calculated. While defining the distances of similarities, the Euclidean distance was used and its pattern is a s follows:

$$d_{il} = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_{lj}\right)^2}, \quad (i, l = 1, 2, \ldots, n), \quad (3)$$

where: d_{il} - distance between the objects i and l,

Z_{ij} - standardized value of the variable x_j for i object,

Z_{lj} - standardized value of the variable x_j for l object.

The visualization of distance matrix is Czekanowski's Diagram. The particular lines and columns are matching successive countries. The bigger the symbol is on the crossing of the line and column, the more similar are the countries as regards the researched characteristics. The most similar objects can be found closest to the main diagonal and the least similar objects as regards the researched characteristics are placed far from the main diagonal (Wójcik 2013).

In Fig. 3 and 4 there are Czekanowski's Diagrams for 2004 and 2013 accordingly.

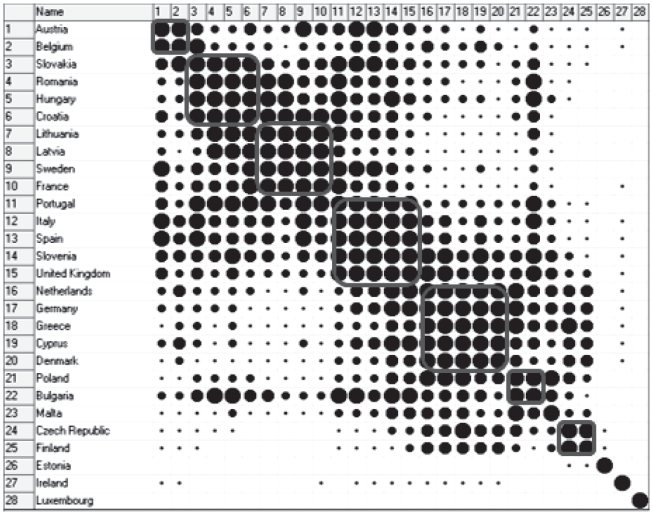

Fig.3. **Czekanowski's Diagram- 2004.**

Source: own study

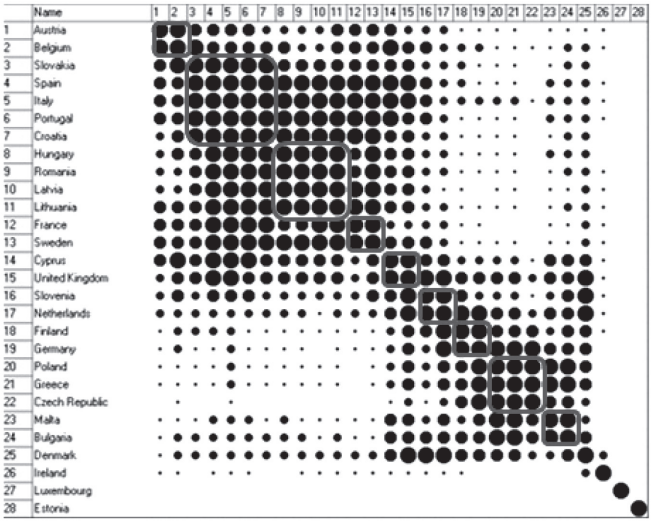

Fig.4. **Czekanowski's Diagram- 2013**

Source: own study

The groups could be made thanks to matching the countries which are most similar. The countries could be matched in a few ways, that is why the choice of the groups is subjective.

In 2004, there were distinguished 7 multi- component groups and 4 countries, which state one-piece groups:

- group 1: Austria and Belgium,
- group 2: Slovakia, Spain, Romania, Hungary and Croatia,
- group 3: Lithuania, Latvia, Sweden and France,
- group 4: Portugal, Italy, Slovenia and the United Kingdom,
- group 5: the Netherlands, Germany, Greece, Cyprus and Denmark,
- group 6: Poland and Bulgaria,
- group 7: the Czech Republic and Finland.

The countries stating one-piece groups are as follows: Malta, Estonia, Ireland and Luxembourg.

While counting the average greenhouse gas emission as per 1000 inhabitants, in particular groups, it turned out that the countries from group no. 7 have the highest emission in energy industry, as well as in manufacturing and construction sector among all other groups. The countries from group no. 1 have the highest average value of emission in transport sector and in industrial processes sector. The countries belonging to group no. 5 have the highest emission in agriculture sector, as well as in industry where the greenhouse gas emission is on the high level. In group no. 4 we could

find the countries which have the biggest trouble with emission connected to waste sector, but they emit the least in industrial processes and agriculture sectors. The average greenhouse gas emission in energy industry, manufacturing and construction and in industrial processes is in group no. 3. The countries belonging to group no. 2 are characterized with the lowest emission connected with the waste sector.

In 2013 there were defined 9 multi-component groups and 4 countries, which state the one-piece groups:

- group 1: Austria and Belgium,
- group 2: Slovakia, Spain, Italy, Portugal and Croatia,
- group 3: Hungary, Romania, Lithuania and Latvia,
- group 4: France and Sweden,
- group 5: Cyprus and the United Kingdom,
- group 6: Slovenia and the Netherlands,
- group 7: Germany and Finland,
- group 8: Poland, Greece and the Czech Republic,
- group 9: Malta and Bulgaria.

The countries stating one-piece groups are as follows: Denmark, Ireland, Luxembourg and Estonia.

In Table 6, there were presented the average values of greenhouse gas emissions as per 1000 inhabitants with the division for economy sectors in particular multi-component groups distinguished in 2013.

Table 6. **Average values of greenhouse gas emissions as per 1000 inhabitants with the division for economy sectors in particular multi-component groups distinguished in 2013.**

Group	Energy industry	Manufacturing and construction	Transport	Industrial processes	Agriculture	Waste
1	1,62	1,27	2,44	1,81	0,85	0,19
2	1,52	0,87	1,51	0,79	0,65	0,39
3	1,26	0,49	1,19	0,61	1,05	0,38
4	0,93	0,91	1,98	0,65	0,97	0,24
5	2,61	0,67	1,69	0,87	0,68	0,39
6	3,20	1,08	2,38	0,60	0,95	0,24
7	4,26	1,57	2,09	0,92	0,98	0,28
8	4,74	0,77	1,45	1,07	0,77	0,40
9	3,94	0,30	1,14	0,57	0,51	0,38

Source: own study

Group no. 9 is characterized by the lowest greenhouse gas emissions in four economy sectors: manufacturing and construction, transport, industrial processes and agriculture. Groups no. 1 and 8 have the highest values in two sectors (transport and industrial processes- group no. 1, energy industry and waste- group no.8). The highest greenhouse gas emission as per 1000 inhabitants in manufacturing and con-

struction sector is in group no. 7, and in agriculture sector in group no. 3. The lowest greenhouse gas emission in energy industry in 2013 was in France and Sweden (group 4).

To sum up, the EU countries create group of countries with a similar structure of greenhouse gas emissions in distinguished economy sectors, but their similarity is not connected with the geographical position, nor with the historical conditions. Moreover, the groups change during the span of researched period.

Conclusions

In this article, the hypothesis that the greenhouse gas emissions were decreasing between 2004 and 2013 in the whole EU, as well as in individual member countries was verified. In fact, the greenhouse gas emission in the EU decreased by 14,5%. In some of the countries, the emission decreased even by over 25%, but there were also countries in which the emission increased. In Latvia, the increase equaled 2,6% and in Estonia 14,6%. The greenhouse gas emissions were the highest in the biggest EU countries.

Analyzing the EU as a whole, the greenhouse gas emission in all of the economy sectors decreased between 2004 and 2009. Stating the highest decrease in waste sector, and the lowest decrease in agriculture sector.

Due to the fact that greenhouse gas emission is strongly connected with the number of inhabitants of researched countries, it was calculated as per 1000 inhabitants. After the recalculation of emission as per 1000 inhabitants, the order of the greatest issuers was completely different in 2004, as well as in 2013. Surprisingly, Finland took the one of the highest positions in this classification. Even after the examining of greenhouse gas emissions in various economy sectors as per 1000 inhabitants in 2013, Finland was always among the biggest poisoners. Luxembourg, the Czech Republic, Belgium and the Netherlands appeared frequently.

To verify the hypothesis that the structure of greenhouse gas emissions depends on the geographical position and historical conditions, the EU countries were divided for homogenous groups as regards the structure of emission. This division was made with the use of Czekanowski's Method for 2004 and 2013. For both periods of time, there were distinguished a few groups with a similar structure of greenhouse gas emissions, but their composition was not conditioned by geographical position, nor by historical conditions. Sweden and Finland can be a very good example. In 2013 Sweden did not appear even once among the biggest poisoners (after the recalculation of greenhouse gas emission as per 1000 inhabitants), while Finland was always among them.

In successive research the area of the researched countries can be taken into consideration. Perhaps not only the amount of inhabitants, but also the area of the country has the influence on the quantity of greenhouse gas emissions.

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Šiltnamio efektą sukeliančių dujų emisija Europos Sąjungos šalių sektoriuose

Anotacija

Šiame straipsnyje buvo patikrinta hipotezė, kad šiltnamio efektą sukeliančių dujų emisija visoje ES, ir ypač kai kuriose valstybėse narėse, mažėja. Atsižvelgiant į tai, kad dujų emisija priklauso nuo gyventojų skaičiaus, ji buvo paskaičiuota 1000 žmonių ir tada buvo tiriami šiltnamio efektą sukeliančių dujų emisijos panašumai įvairiuose ES ekonomikos sektoriuose. Taip pat buvo patikrinta ir kita hipotezė, kad dujų emisija priklauso nuo geografinės padėties ir istorinių sąlygų. Czekanowskio metodas buvo naudojamas dalijant vienarūšes valstybes pagal šiltnamio efektą sukeliančių dujų emisiją skirtinguose ekonomikos sektoriuose. Analizė įrodė, kad išmetamų šiltnamio efektą sukeliančių dujų kiekis mažėja visoje ES, išskyrus dvi šalis, kuriose dujų išmetimas didėja. Panaudojus Czekanowskio metodą buvo padarytos išvados, kad šiltnamio efektą sukeliančių dujų emisija nepriklauso nuo geografinės padėties, nei nuo istorinių sąlygų.

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